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Evaluation of Stream Rehabilitation Projects—Salem District (1981–1988)

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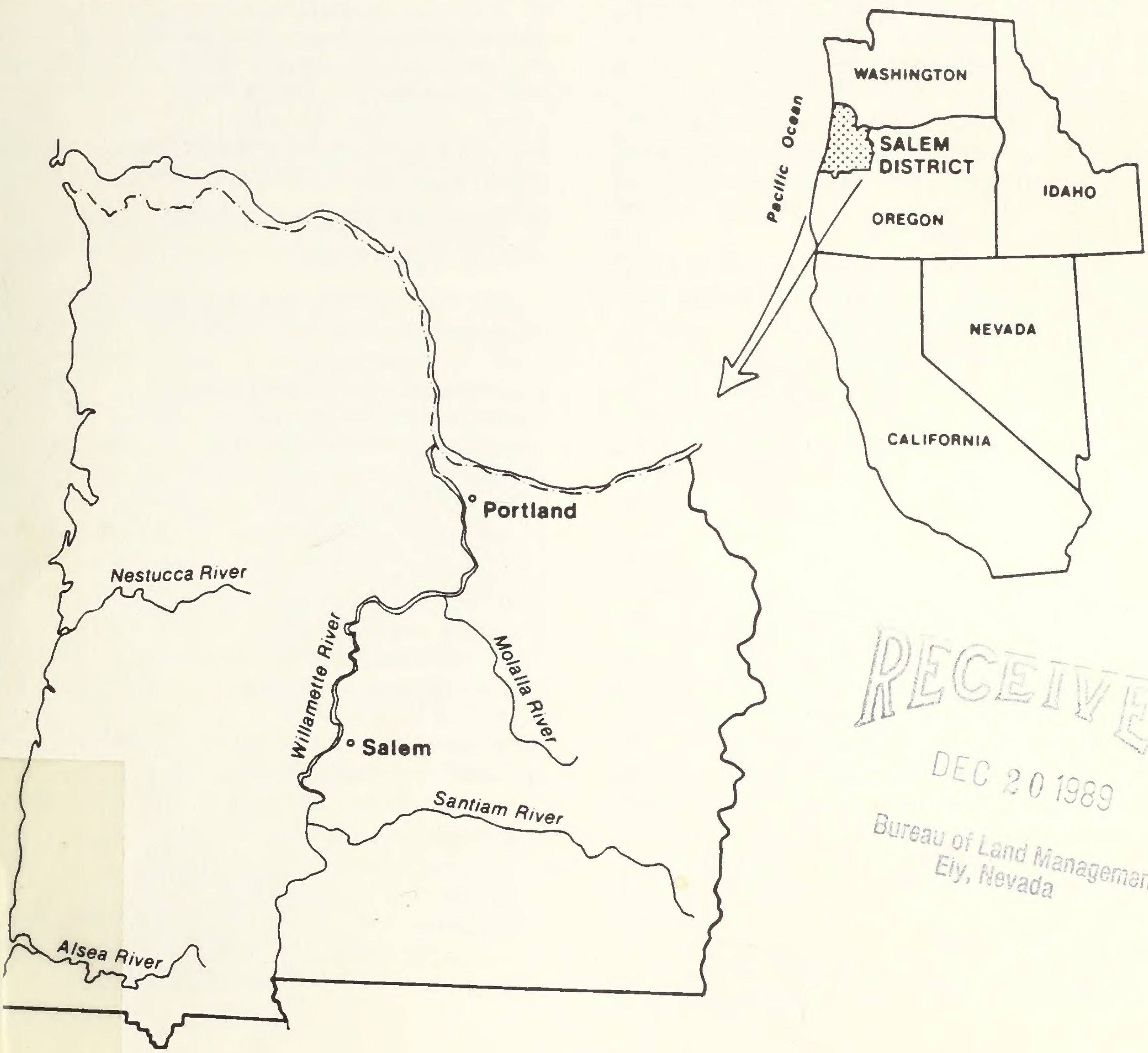

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Abstract

The Salem District (Bureau of Land Management) embarked on an accelerated stream rehabilitation program in 1981, spending $229,800 on 15 projects for 849 instream structures on 10 streams in the Alsea and Nestucca River drainages. Included in the report are physical, biological, and economic evaluations over an 8-year period on over 16 miles of stream, of which about 6 miles were treated.

Of the 812 structures (437 full spanning) installed during 14 construction projects in streams ranging from 10 to 66 feet in width, 86 percent are fully functional, 10 percent damaged functional, 2 percent repairable nonfunctional, and 2 percent unrepairable nonfunctional. Stream size and materials were found to have no bearing on structural success.

In eleven projects evaluated for detailed changes in habitat conditions, narrow riffle areas were converted into long, wide pool habitat. Project work more than doubled the surface area, with the low flow wetted perimeter increasing an average of 22 ft^2 for each 3 feet of treated stream.

The potential increase in populations was an estimated 92,140 juvenile coho, 14,170 trout fry, 6,780 yearling steelhead, and 2,560 sea-run and resident yearling cutthroat. Generally, the greatest increase occurred in channels over 39 feet in width and treated with many full-spanning wood structures. Structures also substantially increased spawning areas and use by adult spawners in reaches treated.

East Fork Lobster Creek is the only project where long-term monitoring has produced sufficient information to derive an accurate estimate of salmon production. This project has shown a fourfold increase in juvenile coho salmon and a thirteenfold increase in adult coho salmon with an average annual ocean catch of 181 fish attributable to the project. All projects produced an estimated annual catch of 2,381 coho salmon, 136 steelhead, and 26 sea-run cutthroat trout. For coho salmon, this represents a commercial catch of 1,667 fish (10,500 pounds) and a sport catch of 714 fish. Estimated annual benefits arising from the total catch amount to $57,048, with an overall B/C ratio of 3.1 after 20 years, 4.7 after 50 years, and 5.1 after 80 years.

Our findings over the last eight years of evaluations have shown that stream rehabilitation work seems to have achieved structural, habitat, biological, and economic success. The restructuring of degraded stream reaches has created significant increases in preferred salmonid habitat. Based on our current knowledge, the best and probably least costly method of rehabilitating streams is through a riparian management policy that provides optimum numbers of all sizes of conifers along all streams used by salmonids. This type of management is especially importat for maintaining and increasing long-term salmonid productivity since only about one-third of the anadromous fish producing areas of coastal streams can be effectively rehabilitated.

Recommendations for future mangement actions are to: (1) Install large full-spanning structures made of natural material (boulders and wood) in large tributaries and upper mainstem rivers to produce the greatest benefits to salmon and trout populations; (2) Manage riparian zones to produce optimum numbers of mature (100-year+) conifers as the least costly long-term method of rehabilitating coastal anadromous salmonid streams; (3) Continue rehabilitation work in key reaches of coastal streams because it is cost effective and a short-term practice that is needed until riparian zones can provide natural structures; and (4) Continue long-term evaluations to determine accurate project benefits.

I. Introduction

In conjunction with our stream rehabilitation project work, the Salem District has, since 1981, embarked on a fairly intensive long-term effort to evaluate and monitor the success and effectiveness of our stream improvement work. This ongoing effort has, to varying degrees, assessed the results of work conducted on ten streams and 15 projects. It has become important that this information be summarized and made available to other BLM districts and agencies or oganizations doing similar types of projects.

Researchers have noted the lack of evaluation findings and the difficulty of evaluating stream rehabilitation projects (Hall and Baker 1982, Everest and Sedell 1984, and Hall 1984). More recently, others have noted a high degree of structure failure with some rehabilitation projects in Oregon and Washington (Frissell and Nawa, in press). That study, however, does not represent a comprehensive look at the wide range of projects constructed in Oregon, and our findings indicate more positive results.

The Salem District has about 110 miles of coastal streams used by anadromous salmonids, of which approximately 16 miles have been partially treated and another 20 miles are in need of treatment. It should be emphasized that Salem's projects, for the most part, have been conducted in stable streams that have experienced severe adverse impacts from past land management activities and natural events. Stream reaches considered to be in good to excellent habitat condition have not and will not be scheduled for treatment. Unstable stream reaches currently in poor or fair condition will not be treated. Stream rehabilitation should be considered an interim, short-term measure until large conifers are reestablished in the riparian zone to provide a source of large woody debris.

The Salem District believes the evaluation information from ongoing monitoring is extremely important and should be available for others to facilitate better assessments of past and future rehabilitation efforts. Although our evaluation has been a long-term and costly effort, we believe the end result is well worth the investment. Through evaluation we can determine such information as:

- better construction techniques
- most successful and least costly methods
- best materials and type of structures
- which stream reaches to treat
- amount and type of habitat structures create
- more accurate b/c ratios

The objective of this report is to evaluate current stream rehabilitation projects in the Salem District by assessment of structural stability, habitat produced, increased salmonid responses, and project benefits.

II. Study Areas

Thirteen of the 15 rehabilitation projects were in either the upper Lobster Creek or upper Nestucca River drainages (Table 1). Tobe Creek project was located in the South Fork Alsea River drainage and the East Beaver Creek project was in the Beaver Creek drainage of the lower Nestucca River. Completed projects have treated 34 percent (5.7 miles) of the 16.6 miles of coastal streams in the Salem District, with drainages ranging in size from 640 to 12,676 acres (Table 1).

Upper Lobster Creek—Located in the headwaters of Lobster Creek, the largest tributary to the Five Rivers system of the Alsea River, this drainage experienced severe impacts from intensive forest management activities and the 1964 100-year storm event. The District has completed the Upper Lobster Creek report (House and Boehne 1987), which assessed habitat, water quality conditions and fish use throughout 10.3 miles of stream used by anadromous salmonids. To date, approximately 2.1 miles have been treated in this drainage, including East Fork Lobster Creek projects (1981 and 1987), Upper Lobster Creek projects (1982 and 1987), and "J" line and Lobster Creek projects (1987). Additional habitat improvement projects identified in this report include work on the upper and lower mainstem Lobster Creek and East Fork Lobster Creek. Identified future work includes construction of additional boulder and log structures,

Table 1. Costs, stream length treated, drainage area, stream size, and number of structures installed for Salem District (BLM) rehabilitation projects

Projects (Year)	Cost ($)	Reach Length (ft)	Treated Length (ft)	Drainage Area (acres)	Channel Width (ft)	Number of Structures
Alsea R.A.						
E.F. Lobster (1981)	20,000	5,250	1,640	3,600	39	45
Tobe (1982)	15,800	5,280	574	2,290	16	20
Upper Lobster (1982)	8,000	2,120	300	1,300	26	9
S.F. Lobster (1982)	1,200	3,000	2,500	640	10	65
Little Lobster (1986)	13,000	3,180	1,920	4,594	36	142
"J" Line (1987)	2,400	8,450	1,300	1,035	13	29
Lobster (1987)	10,600	4,000	1,000	11,328	47	37
Upper Lobster (1987)	5,600	480	170	2,822	19	14
E.F. Lobster (1987)	2,400	5,250	600	3,000	39	11
Tillamook R.A.						
E. Beaver(1983)	24,600	2,100	1,000	1,600	30	32
Testament (1985)	1,200	5,280	1,050	3,050	20	37
Upper Nestucca (1986)	55,000	27,900	10,240	8,840	56	197
Lower Elk (1986)	25,000	6,230	2,800	6,573	46	92
Middle Nestucca (1987)	22,000	5,670	3,700	12,676	60	42
Upper Elk (1987)	23,000	3,200	2,150	4,300	44	77
Total	229,800	87,390	29,865			849

secondary channels, and includes the proposal to plant cedar and/or hemlock along 10.3 miles of stream to hasten the reestablishment of natural large woody instream structures.

Upper Nestucca River—Elk Creek and Nestucca River projects were included in habitat improvement priorities listed in the "Nestucca River Basin Anadromous Salmonid Habitat Overview" by Baker et. al. (1986). This report, approved by managers from the U.S. Forest Service (Hebo Ranger District), BLM (Tillamook Resource Area and Salem District), and ODFW (Columbia Region) outlines current habitat conditions and needs for the entire Nestucca River Basin. Additional work described in this report includes treatment of the remainder of Elk Creek and the Nestucca River, and new work on Bear, Fan, and Ginger Creeks planned within the next 2-3 years. Future work will also include fish passage and instream rehabilitation of Elk and Tucca Creeks, if and when ODFW provides fish passage at Elk Creek falls (located 2.8 miles upstream from the mouth).

III. Materials and Methods

A. Materials

From 1981 to 1983, most rehabilitation work was accomplished using gabion structures (generally with fill material from onsite sources), whereas projects completed from 1984 to 1987 relied completely on the use of natural materials, primarily large woody material and boulders taken from on and offsite sources (Table 2).

B. Contracts

Most contracts were equipment rentals. Medium-sized caterpillar tractors, costing bewteen $50-$60 per hour, were used to install gabion structures, whereas track-mounted excavators, costing about $90-$100 per hour were used to install logs, rootwads, and boulders. On the Testament Creek Project, a timber sale contract was modified at the cost of $50 per tree bole to pay the logger to yard nonmerchantable trees into the stream.

Table 2. Materials and types of structures installed for Salem District (BLM) rehabilitation projects

	Structure Materials			Structure Types							
Projects (Year)	Gabion	Wood	Boulders	Dam	Deflector	Diversion	Cover	Scour	Riprap	Gravel	Other
Alsea Area											
E.F. Lobster (1981)	15	4*	26	19	2		24				
Tobe (1982)	20			18	2						
Upper Lobster (1982)	7		2	7	1				1		
S.F. Lobster (1982)		61	4	1	49		11	4			
Little Lobster (1986)		7*	135	17	13		109		3	2	
"J" Line (1987)	2	14*	13	13	11		4	1			
Lobster (1987)		9*	23	23	5		9				
Upper Lobster (1987)		7	7	4	6		1	3			
E.F. Lobster (1987)		6	5	5	6						
Tillamook Area											
E. Beaver (1983)	18	2	12	19	2	1	9				1
Testament (1985)		37		15							
Upper Nestucca (1986)		113*	84	82	42	9	56	3			5
Lower Elk (1986)		55*	37	39	7	7	39				
Middle Nestucca (1987)		41	1	7	23	2	42	6			
Upper Elk (1987)		50	27	18	7		52				
Total	62	406	381	294	191	19	318	17	4	2**	6

*Combination of wood and boulders.

**Not included as structures.

C. Evaluation

Four major types of monitoring are being conducted on 15 projects: habitat, juvenile sampling, adult sampling, and structural. The length of sampling has ranged from zero to seven years for both pre- and post-surveys, depending on the type of monitoring (Table 3).

1. Habitat—Habitat assessment was conducted following descriptions of Bisson, et al. (1982), where the channel was divided into pools, riffles, and glide habitat types. Habitat was then quantified by physical aspects of stream character including stream length, width, depth, substrate, and cover for each individual type. Length and width of each microhabitat unit were measured to the nearest foot using a hip-chain and average depth (nearest tenth-foot) was derived from a series of measurements taken within each unit. Dominant substrate of each microhabitat was determined visually by size class of bottom material and major components of cover habitat recorded; e.g., boulder edge, deep pool, undercut banks. Large, stable woody structure was also measured and recorded. Pre and post assessments were conducted during similar flow conditions.

2. Juvenile Sampling—Juveniles were sampled after blocking individual habitat units and then electroshocking and/or beach seining. Populations in each unit were calculated by either the depletion method (two or more passes) or total removal. Sampling usually involved replicate samples on treated and control sites. Numbers of juveniles produced by each project were estimated by multiplying densities (as determined by fish sampling) by the amount of habitat produced. In the absence of fish sampling, we estimated potential summer populations of coho juveniles by multiplying actual habitat produced by coho rearing densities as determined by Reeves et. al. (1988).

3. Adult Sampling—Spawning counts were usually made weekly depending on flow levels and frequency of freshets, with numbers of adults and completed redds recorded for each count. Counts were also conducted on both treated and untreated control reaches.

4. Structural—Structural monitoring was conducted the following summer and/or after greater than annual storm events. Information recorded on structure monitoring included: numbers, types, location, material, size,

Table 3. Types and years of pre and post monitoring of stream rehabilitation projects in the Salem District (BLM)

	Pre			Post			
		Fish			Fish		
Projects (Year)	Intensive1/ Habitat	Juvenile	Adult	Intensive1/ Habitat	Juvenile	Adult	Structural
Alsea R.A.							
E.F. Lobster (1981)	0	1	1	2	7	7	1
Tobe (1982)	1	1	2	1	2	2	1
Upper Lobster (1982)	1	1	1	1	2	2	1
S.F. Lobster (1982)	0	1			1		1
Little Lobster (1986)	1	3	4	1	2	2	1
"J" Line (1987)	2	4	4	1	1	1	1
Lobster (1987)	1	2	1	1	1	0	1
Upper Lobster (1987)	1	4	4	1	1	1	1
E.F. Lobster (1987)	0	7	7	1	1	1	1
Tillamook R.A.							
E. Beaver (1983)	1	1	1	1	5	6	1
Testament (1984)	1	1	0	1	0	0	1
Upper Nestucca (1986)	1	2	2	1	1	3	1
Lower Elk (1986)	1	3	3	1	1	3	1
Middle Nestucca (1987)	1	2	2	1	1	2	1
Upper Elk (1987)	1	1	3	1	1	2	1

1/Intensive includes microhabitat channel monitoring survey.

shapes, success, problems, how secured, habitat created, and fish use. Channel widths and drainage size were also determined (Table 1).

5. **Production**—Annual production of adult coho, steelhead, and sea-run cutthroat was estimated by determining the increase in summer rearing habitat and calculating the increase in young fish from available research (Reeves et al. 1988) and/or site-specific monitoring. Survival estimates and average sport and commercial catch rates provided by Oregon Department of Fish and Wildlife (ODFW) were used to calculate total adult fish produced and caught.

Benefit/cost ratios were determined in the State Office by a microcomputer program developed by the State Office economist, Dale Bays. The ex-vessel price paid per pound to commercial fishermen, dressed weight of commercially caught fish, harvest rates and activity days per fish for different sport fisheries by species, value per activity day, and distribution of inland and ocean sport and commercial catch were provided by ODFW for the BLM's "5-Year Comprehensive Anadromous Fish Habitat Enhancement Plan for Oregon Coastal River (1985)."

D. Costs

To date, approximately $229,800 has been spent on Salem's stream restoration projects (Table 1).

1. **Installation**—Installation costs varied depending on the type of structures installed:

	Gabion Structures	Wood and Boulder Structures
	Percent of costs	
Administration	20	12
Labor	20	15
Materials	20	11
Contract	40	62

Gabion structures had lower equipment contract costs and higher administrative, labor, and material costs (proportionately) than those costs associated with the installation of wood and boulder structures.

2. **Structures**—Costs of structures varied widely depending on how they were installed, access, and materials:

Structures	Cost per structure
<u>Full-spanning</u>	
Gabions	$800-1,200
Large wood (good access)	$200-600
Large wood (remote)	$800-1,300
Boulders	$200-600
<u>Partial spanning</u>	
Deflectors	$140-200
Cost/scour	$10-70
Boulder groupings	$5-50
<u>Secondary channels</u>	$200-1,000 or $1.50/foot

3. **Monitoring**—The costs of monitoring has varied by project; however, the District generally uses from 4-6 temporary and/or permanent workmonths of time, annually, including collection of field data, analysis and write-up. At an average cost of $2,500 per workmonth, the total yearly cost would range from $10-15,000. Not included in these costs is two to four SCA's or volunteers that assist in collecting information.

IV. Results

A. Overall Project Findings

1. **Structures**—The success of structures providing intended habitat was extremely high for all projects (Table 4). Overall structural success was reflective of channel stability, not stream size. In the South Fork of Lobster Creek (the smallest treated stream), the channel was highly unstable at treatment. Consequently, 17 of 65 (26 percent) structures were stranded out of the low flow channel. In contrast, structures installed in the highly stable channels of the Upper Nestucca River and Upper Lobster Creek (the largest streams treated) experienced 97 percent and 95 percent success rates, respectively, for 197 and 43 structures. Of the 812 structures installed in 14 projects, 86 percent are fully functional, 10 percent damaged functional, 2 percent repairable nonfunctional, and 2 percent unrepairable nonfunctional (Table 4). An analysis of full-spanning structures, which have the highest failure rates, shows that stream size and materials were not major factors determining structural success. Installed in streams with channel widths ranging from 3 to 20 meters, full-spanning structures had success rates ranging from 77 percent to mostly 100 percent (Figure 1).

To increase the number of projects evaluated over a larger geographic area, the success of structures installed in the Coos Bay and Medfords Districts were included in the analysis depicted in Figure 1. Combination structures constructed of wood and boulders were the least successful, whereas all gabion and most large wood structures were the most successful. However, the longevity of gabions is limited. For example, some structures installed in 1981 and 1982 are already experiencing deterioration of the wire mesh.

Table 4. Structural success of Salem District's (BLM) rehabilitation projects

Projects	Structure Success: Fully Functional	Damaged Functional	Repairable Nonfunctional	Unrepairable Nonfunctional
Alsea R.A.				
E.F. Lobster (1981)	43	2		
Tobe (1982)	20			
Upper Lobster (1982)	9			
S.F. Lobster (1982)	48			17
Little Lobster (1986)	137	2	3	
"J" Line (1987)	26	2	1	
Lobster (1987)	27	8		2
Upper Lobster (1987)	10	3	1	
E.F. Lobster (1987)	9	2		
Tillamook R.A.				
E. Beaver (1983)	32			
Testament (1984)	–	–	–	–
Upper Nestucca (1986)	148	44	5	
Lower Elk (1986)	80	9	3	
Middle Nestucca (1987)	32	4	6	
Upper Elk (1987)	74	3		
Total	695	79	19	19

– Not present.

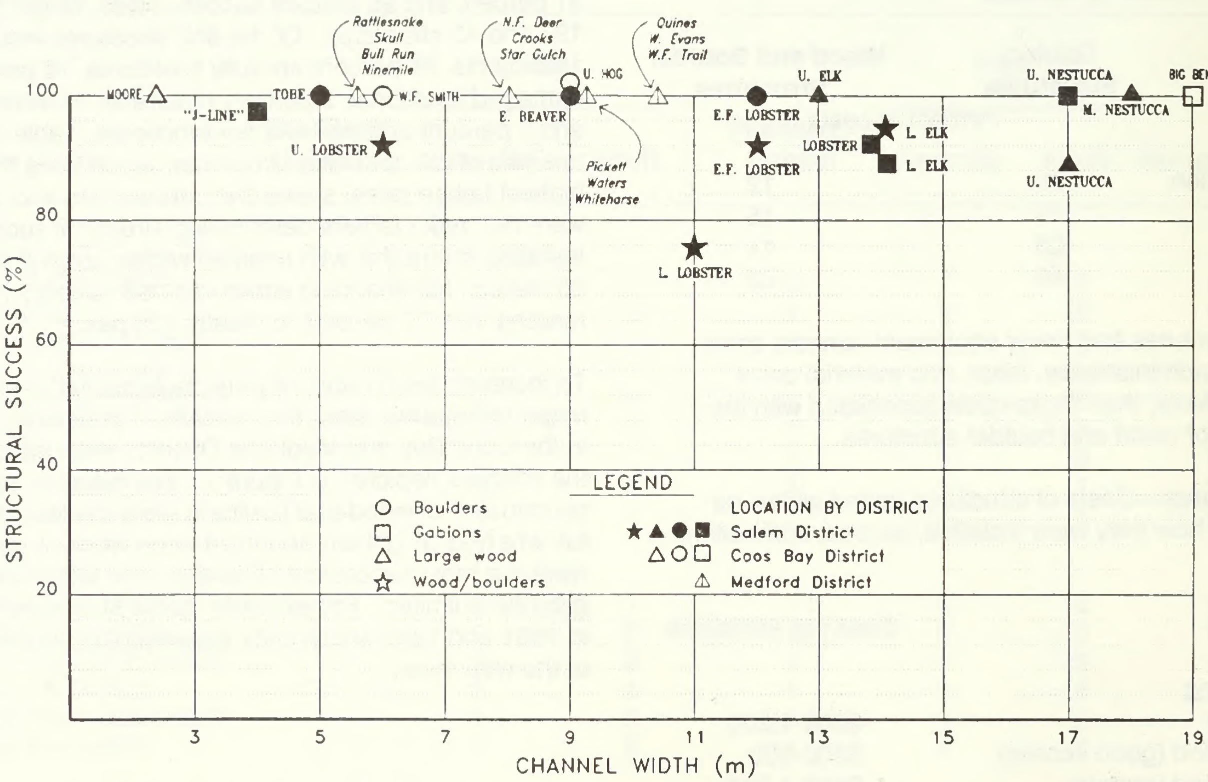

Figure 1. Success rate of full-spanning structures (10 or more) constructed of different materials installed in various sized streams in western Oregon by the Bureau of Land Management, 1980-88.

Design shape of the 437 full or partial spanning structures installed was as follows: 89 were "V"; 3 were "W"; 244 were diagonal; 8 were "Y"; 75 were semi-circles; 1 was a diamond "V"; 5 were "T"; and 12 were perpendicular. Other cover/scour structures were installed as tight boulder groupings (167), loose boulder groupings (87), single large boulders (17), rootwads (23), mini-logjams (4), whole large alder trees (3); and combinations of wood and boulders (110). There was no difference between the shape and success of structures. Also, four unstable banks composed of silts and clays were riprapped. A total of 186 structures were secured by cables, 104 by rebar, 152 by large boulders, and 149 entrenched into the banks.

Problems included 17 structures isolated out of the channel (S.F. Lobster Creek), 27 boulder dams partially broken out, 25 logs scoured under, 2 structures cutting into the bank, 5 structures completely washed away, 7 structures with cable hole fractures, and 3 structures with rebar dislodged. Most structural damage resulting in reduced depth and size of intended summer pool habitat occurred because boulder dams were not secured with cables and single log dams were not wide enough to prevent underscour.

2. Habitat Changes—Of the 15 projects in the Salem District, 11 were evaluated for detailed changes in habitat conditions. Project work increased habitat by 50,368 m^2 of water surface (on the average 2 m^2 per meter of stream) and produced shifts in habitat types (Table 5). Generally, structures increased dam, plunge, and backwater pools, while low and high gradient riffle and glide habitats decreased. Also, projects with planned off-channel work (Lower Elk and Middle and Upper Nestucca) showed substantial increases in secondary channel riffle and pool habitat. The major change occurred in the amount of pool habitat, with the percentage of pool habitat generally doubling and the total amount of pool habitat increased substantially (Table 6).

The amount and variability of pool habitat (surface area) created by fully functional, full-spanning structures depended on channel width (Figure 2). Structures installed in channels ranging from 3 to 11 meters (10 to 26 feet) in width created pool habitat that averaged less than 100 m^2 and varied from 10 m^2 to less than 200 m^2. Conversely, structures installed in channels ranging from 14 to 20 meters (45 to 66 feet) in width created pool habitat that averaged 200 m^2 to 1,000 m^2 and varied from 50 m^2 to over 2,100 m^2.

Structures increased the water storage of streams by 22,586 m^3 during the summer. Water volume increased two to threefold after treating Lobster Creek, Upper and Middle Nestucca River, and Lower and Upper Elk Creek projects. This increase generally translated into an increase of about 1 cubic meter of water per meter of treated stream.

Table 5. Changes in available habitat attributable to rehabilitation projects, Salem District (BLM)

	Habitat Types (m^2)											
	Pools							Riffles			Structure Nos.	
Project (Year)	Dam	Backwater	Lat. Scour	Plunge	Trench	Sec. Chann.	Glides	Low Grad.	High Grad.	Sec. Chann.	Full Spanning	Partial Spanning
Alsea R.A.												
E.F. Lobster (1981)	+1,125	+122	+45	+202	+63	NC	+127	+214	-260	+31	19	26
Tobe (1982)	+157	+6	NC	+52	NC	NC	+233	-160	-40	NC	18	2
Little Lobster (1986)	+464	+100	+486	-17	-1,689	NC	+318	-501	NC	+68	17	125
"J" Line (1987)	+246	+48	+68	+20	NC	NC	-59	+91	-247	NC	13	16
Upper Lobster (1987)	-27	+87	+130	+14	-64	+36	-125	+18	NC	+28	4	10
Lobster (1987)	+3,322	+78	-349	+223	-99	+40	-1,210	+416	-161	+390	23	14
Tillamook R.A.												
E. Beaver (1983)	+1,306	-110	+36	+121	-41	+6	+61	-337	-1,043	-17	20	12
Upper Nestucca (1986)	+24,613	-490	-8,578	+1,829	+3,365	+1,245	+10,258	-2,289	-1,312	+1,612	91	106
Lower Elk (1986)	+6,345	+355	+67	-589	+59	+573	-619	-24	-214	+1,614	46	46
Middle Nestucca (1987)	+7,450	+2	-45	+531	-153	+886	-1,497	-1,699	+68	+169	7	35
Upper Elk (1987)	+4,302	+287	-178	+310	NC	-82	-546	-980	-403	+84	18	59
Total	+49,303	+485	-8,318	2,696	+1,441	+2,704	+6,941	-5,251	-3,612	+3,979		

NC = No change or not present.

Table 6. Percentage of a stream reach treated and changes in percent of pool, pool habitat, and total habitat of 11 stream reaches

Stream (project)	Percent Treated	Percent Pool Pre	Percent Pool Post	Change in Pool Habitat (m^2)	Change in Available Habitat (m^2)
E.F. Lobster	31	46	63	+1,557	+1,669
Tobe	11	12	18	+218	+248
Little Lobster	60	63	62	-654	-763
"J" Line	52	19	48	+382	+167
Upper Lobster	47	40	54	+176	+97
Lobster	40	17	38	+3,215	+2,650
E. Beaver	47	11	60	+1,318	-18
Upper Nestucca	37	26	50	+21,984	+30,253
Lower Elk	45	14	47	+6,810	+7,567
Middle Nestucca	36	29	76	+8,671	+5,712
Upper Elk	67	23	77	+4,639	+2,794

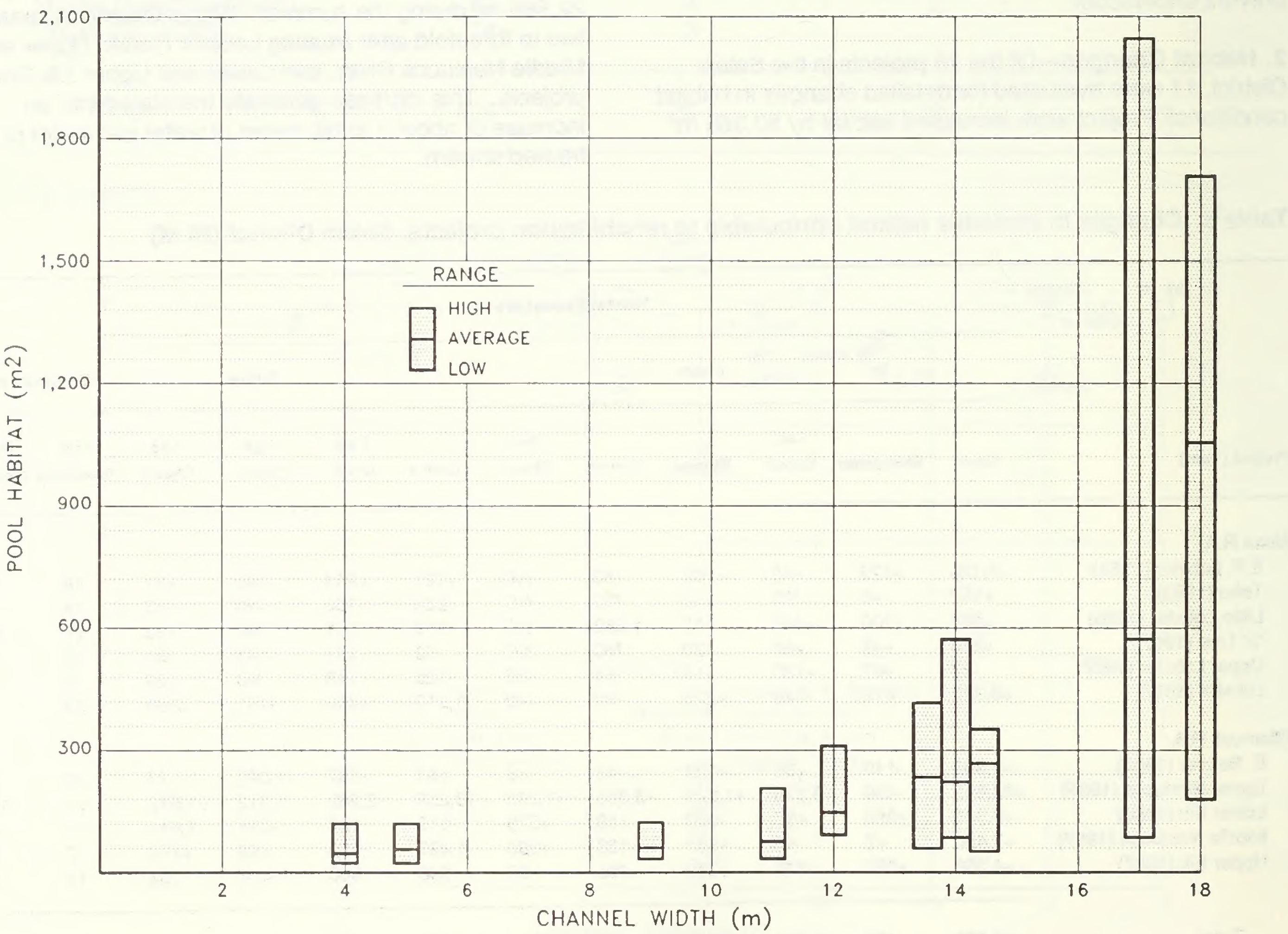

Figure 2. Amount of summer pool habitat created by fully functional full-spanning structures installed in streams with varying channel widths.

The amount and variation of bedload trapped per structure varied depending on the width of the stream channel (Figure 3). Channels less than 9 meters in width trapped an average of 15 m^2 of bedload, with the maximum amount less than 50 m^2. Streams with channel widths ranging from 9 to 14 meters (30 to 46 feet) recruited an average of 60 m^2 to 100 m^2 of bedload, with a maximum of about 250 m^2. However, structures placed in streams with channel widths greater than 15 meters (50 feet) showed substantial increases and wide fluctuations in trapped bedload. Wide fluctuations in amounts of trapped bedload were caused by site-specific conditions (gradient and channel width) and structure height. Some structures are expected to trap substantially more bedload overtime, while scour structures and site specific natural hydrological scour will continue to push added bedload over or around other structures.

3. Fish Populations—

a. *Summer Juveniles*

Estimated or potential increases in juvenile salmonid densities and populations (92,140 juvenile coho, 14,170 cutthroat and steelhead trout fry, 6,780 steelhead parr, and 2,560 cutthroat parr) occurred after treating portions of 12 streams (Table 7). Increases for specific projects varied by fish species and their age, size, condition of stream, intensity and types of treatment, and adult escapement.

Different projects had varying salmonid juvenile responses, with coho salmon showing the biggest increases and cutthroat trout yearlings changing the least (Table 8). After treatment, increases in coho juveniles ranged from a maximum of 17.9 fish per meter of treated Lower Elk Creek to a minimum of 0.5 in Upper Lobster Creek. Changes in trout fry ranged from a maximum of 5.7 fish per meter of treated E.F. Lobster Creek to a decrease of 0.2 in Upper Lobster Creek. Steelhead yearling changes ranged from 2.2 fish per meter of treated Lower Elk Creek to a decrease of 0.1 in Upper Lobster Creek. Cutthroat trout yearlings increased a maximum of 1.1 fish per meter of treated Lower Elk Creek to no change in three streams.

The response of juvenile salmonids to treatment varied in streams with different channel widths (Figure 4 and Table 8). Coho salmon juveniles showed substantial increases in streams with channels greater than 12 meters (39 feet),

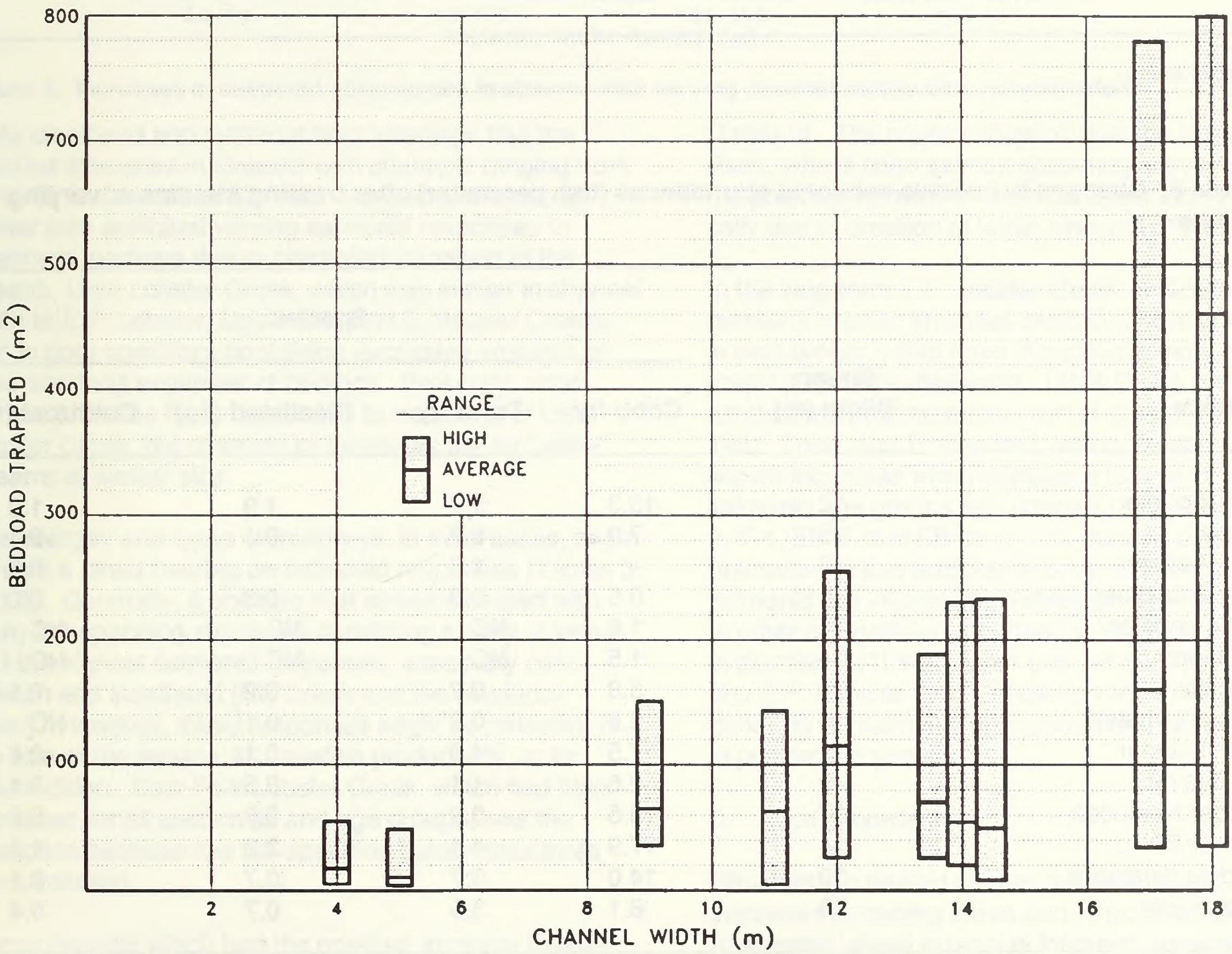

Figure 3. Amount of bedload trapped by fully functional full-spanning structures installed in various sized streams.

Table 7. Estimated potential or measured average annual increases in summer juvenile salmonid populations and changes in spawning activity after treatment, Salem District (BLM)

	Salmonid Juvenile Nos.				Redd Nos.			
Project (Year)	Coho	Trout fry	Steelhead Parr	Cutthroat Parr	Coho Redds	Chinook Redds	Steelhead Redds	Study Reach Length (m)
E.F. Lobster (1981)	+6,650	+2,850	+927	+520	+99	+4	+36	500
Tobe (1982)	+1,206	+32	+22	+6	+13	–	+23	152
S.F. Lobster (1982)	–	+112	–	+28	–	–	–	61
Upper Lobster (1982)	+49	+346	+23	+18	NC	–	+10	91
Little Lobster (1986)	+597	NC	NC	NC	-27	NC	-5	585
"J" Line (1987	+580	+8	-8	-13	+5	–	-6	396
Lobster (1987)	+4,376	+226	+271	+68	–	–		1,149
Upper Lobster (1987)	+241	-29	-14	+3	–	–		122
E.F. Lobster (1987)	+228	+122	+3	+17	–	–		30
E. Beaver (1983)	+1,638	+728	+322	+90	+3	–	+40	640
Upper Nestucca (1986)	+46,160	+2,850	+2,375	+475	-3	NC	NC	3,121
Lower Elk (1986)	+15,280	+3,725	+1,860	+950	+4	+2	+9	853
Middle Nestucca (1987)	+8,645	+403	+421	+70	NC	NC	+6	617
Upper Elk (1987)	+6,487	+2,794	+582	+323	+12	NC	+9	975
Total	92,137	14,167	6,784	2,555				

NC = No measurable change.

Table 8. Changes in juvenile salmonid abundances (fish per meter) after treating streams of varying widths

		Species			
Stream	Stream Width (m)	Coho fry	Trout fry	Steelhead (1+)	Cutthroat (1+)
E.F. Lobster	12	13.3	5.7	1.9	1.0
Tobe	5	7.9	0.2	0.1	>0.1
S.F. Lobster	3	–	1.8	–	0.5
Upper Lobster	8	0.5	3.8	0.3	0.2
Little Lobster	11	1.0	NC	NC	NC
"J" Line	4	1.5	NC	NC	NC
Lobster	14	3.8	0.2	0.2	0.1
Upper Lobster	6	2.0	0.2*	0.1*	NC
E.F. Lobster	12	7.5	4.0	0.1	0.6
E. Beaver	9	2.6	1.1	0.5	0.1
Upper Nestucca	17	13.5	0.9	0.8	0.2
Lower Elk	14	17.9	4.4	2.2	1.1
Middle Nestucca	20	14.0	0.7	0.7	0.1
Upper Elk	13	8.1	3.5	0.7	0.4

NC = No measurable change.

*Decrease in fish per meter of stream.

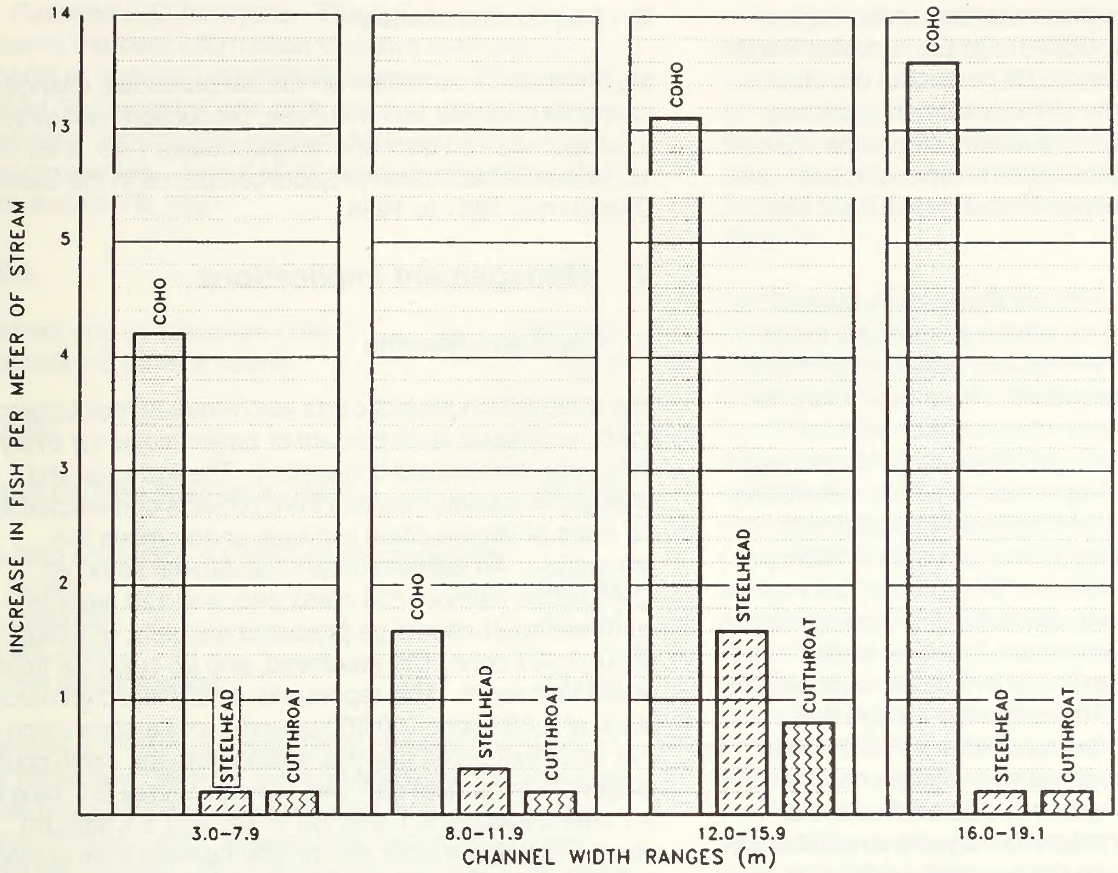

Figure 4. Increases in salmonid abundances in streams with varying channel widths after rehabilitation.

while steelhead and cutthroat trout yearlings had the greatest increases in streams with channels ranging from 12 to 16 meters (39 to 52 feet). However, streams of similar size exhibited varying salmonid responses to treatment, perhaps due to preproject condition of the stream. Little Lobster Creek, which was similar in channel width to E.F. Lobster, Upper Elk, and E. Beaver Creeks, was in poor condition, containing excessive amounts of fines and long expanses of bedrock. Presently, coho salmon juveniles have responded to treatment of Little Lobster Creek, but changes or increases are far below streams of similar size.

The intensity and types of treatment, in most cases, seem to have a direct bearing on salmonid responses (Tables 3 and 6). Generally, it appears that streams treated with many full-spanning structures consisting mostly of wood had the highest salmonid responses, especially coho salmon and steelhead (Elk Creek and the Nestucca River). However, these responses might be reflective of the size of the stream, its baseline productivity, or its precondition. East Fork Lobster Creek, which had high increases for all salmonids and age groups, was the exception because few full-spanning gabion structures were installed.

Those projects which had the greatest increase in numbers of completed redds, a measure of adult coho salmon use, generally had the highest increases in coho juveniles (Table 6). The major exception was the Upper Nestucca River, where coho salmon spawning activity declined but the potential number of coho juveniles increased dramatically due to creation of large amounts of preferred habitat.

In the long-term E.F. Lobster Creek evaluation, the numbers of coho juveniles produced from adults returning in post project years have increased almost fourfold over preproject levels (Appendix, Table EF-4). In projects with established treatment and control sites (E.F. 'Lobster 1981, Tobe, and E. Beaver Creeks), treatment sites have shown increases when compared to control sites for all salmonid age groups and species (Appendix, Tables EF-3, T-1, EB-5, and EB-6). In site specific evaluations, the restructuring and addition of cover dramatically increased salmonid use (Appendix, Tables UL-1, EFL-2, and EB-7). In other evaluations with three or more preproject years of evaluation ("J" Line, Upper Lobster 1987, Little Lobster and E.F. Lobster 1987), showed varied results, but generally all salmonid age groups and species increased in postproject years.

b. Adult Spawners

Structures in treated stream reaches have substantially increased spawning areas and in most streams adult use. In streams where extensive longterm spawning ground counts have been conducted (E.F. Lobster, E. Beaver, and Lower and Upper Elk Creeks), increases in adult

spawners and redds have occurred (Appendix, Tables EF-1, EF-2, EB-3, LEC-2, UEC-3). In E.F. Lobster Creek, 52 percent of the coho salmon, 65 percent of the steelhead, and 73 percent of the chinook salmon spawning occurred in areas created by treatment structures. Over a 7-year period, the average number of redds per year (all species combined) has ranged from 3.1 to 5.7 per structure in E.F. Lobster Creek.

4. Production—The E.F. Lobster Creek evaluation is the only project that has been monitored in sufficient detail and duration to arrive at a reasonably accurate estimate of increased salmonid production. This project has produced thirteenfold increase in coho salmon, with an average annual catch of 181 fish attributable to the project (Appendix, Table EF-5). The increase in coho salmon, in conjunction with increases of steelhead and cutthroat yearlings, produces an average annual value of $269 per full-spanning structure installed in E.F. Lobster Creek (Table 9). For other projects, generally the increase in summer juveniles per structure was higher in larger streams (Nestucca River and Lobster Creek) compared to smaller tributary streams (Tobe and "J" Line Creeks). However, treating major tributary streams (E.F. Lobster and Elk Creeks) that presently or potentially have high fish use resulted in substantial gains in salmonid use. As shown in Figure 4, these major tributary streams (12 to 16 meters in width) have shown the greatest potential to increase steelhead and cutthroat yearlings as well as substantially increase coho juveniles.

B. Project Summaries

More detailed information on habitat produced, changes in salmonid juveniles and adult use, production, and structural success can be found in Appendices 1-15, a list of 15 stream rehabilitation projects completed in the Salem District from 1981 to 1988.

V. Management Implications

A. Costs and Benefits

The $229,800 in project costs also requires maintenance costs, estimated at 10 percent of project costs for every 10th year after project completion. The increase and changes in habitat resulting from projects constructed in 16 miles of stream could increase anadromous fish production. An estimated 3,917 additional adult fish (3,450 coho salmon, 339 steelhead, and 128 sea-run cutthroat trout) should be produced annually, of which about 2,381 coho, 136 steelhead, and 26 cutthroat trout would be caught. This represents a potential commercial catch of 1,667 coho (10,500 pounds) and a sport catch of 714 fish. Estimated benefits arising from the catch could amount to an annual $57,048, with an overall B/C ratio of 3.1 after 20 years, 4.7 after 50 years, and 5.1 after 80 years. This figure does not include benefits from chinook salmon production, which occur in the E.F. Lobster (1981), Little Lobster, Lobster, and the Nestucca River, E. Beaver and Elk Creek projects.

Table 9. Estimated annual benefits and costs derived from full-spanning structures installed in 10 streams

	Increased juveniles/ structure			Smolts produced1/			Adults produced2/			Catch/structure3/			Annual Value ($)4/			
Project (year)	Coho	Steel-head	Cut-throat	Coho	Steel-head	Cut-hroat	Coho	Steel-head	Cut-throat	Coho	Steel-head	Cut-throat	Coho	Steel-head	Cut-throat	Cost/ Structure5/
E.F. Lobster (1981)	350	49.0	27.0	175	25.0	13.5	13.1	2.5	1.4	9.0	1.0	0.3	163	103	3	900
Tobe (1982)	67	1.2	0.3	34	0.6	0.5	2.6	0.1	0.1	1.8	0.1	0.1	20	10	1	700
Little Lobster (1986)	35	0.0	0.0	18	0.0	0.0	1.4	0.0	0.0	0.9	0.0	0.0	11	0	0	400
Lobster (1987)	190	12.0	3.0	95	6.0	1.5	7.1	0.6	0.2	4.9	0.2	0.1	85	20	1	600
"J" Line (1987)	70	2.2	3.1	35	1.0	1.6	2.6	0.1	0.2	1.8	0.1	0.1	20	4	1	200
E. Beaver (1983)	82	16.0	5.0	41	8.0	2.5	3.1	0.8	0.3	2.1	0.3	0.1	43	31	1	1,200
Upper Nestucca (1986)	463	26.0	5.0	231	13.0	2.5	17.3	1.3	0.3	11.9	0.5	0.1	228	52	1	500
Lower Elk (1986)	332	40.0	21.0	166	20.0	10.5	12.5	2.0	1.1	8.6	0.8	0.2	163	83	3	450
Middle Nestucca (1987)	1,235	60.0	10.0	618	30.0	5.0	46.0	3.0	0.5	32.0	1.2	0.1	385	124	1	1,300
Upper Elk (1987)	360	32.0	18.0	180	16.0	9.0	13.5	1.6	0.9	9.3	0.6	0.2	166	62	2	1,000

1/Smolts were determined by using a 50% juvenile survival.

2/Smolt to adult survival was 7.5% for coho salmon and 10% for steelhead and cutthroat.

3/Estimated catch was: 69% for coho salmon; 40% for steelhead; and 20% for cutthroat.

4/Annual values were calculated using the same methods as the "Five-year Comprehensive Anadromous Fish Habitat Enhancement Plan for Oregon Coastal Rivers," BLM, 1985.

5/Estimated cost of constructing a full-spanning structure.

1. Detailed B/C Analysis—The E.F. Lobster Creek presents the best information to derive estimates of benefits of a stream rehabilitation project. This project treated 30 percent of one-mile reach of stream that was previously impacted by logging, 100-year flood, and stream cleaning. A total of 45 structures (mostly gabions) were installed in 1981.

<u>Costs</u>

Contract and construction (1981)	$20,000
Maintenance (after 8 years)	5,000

<u>Benefits</u>

Annual benefits (starting in 1983)	$3,613

B/C ratio (20 years, 4.0 percent discount rate)

Costs	22,744
Benefits	42,287
B/C ratio	1.86
Net present value	19,544

However, if the E.F. Lobster Creek Project had used a less expensive material, such as boulders, the total cost would probably have been reduced by 2/3 to approximately $6,600. Also, substantially less maintenance would be required. The net species value in 1985 alone was $7,232. Only coho salmon, steelhead and cutthroat trout were used to derive benefits. Chinook salmon spawning has increased substantially since project construction, but no benefits were attributed.

B. Future Recommendations

The evaluation of our rehabilitation projects has revealed some important facts which will aid in planning, constructing and managing future projects and riparian zones.

1. Structure types—Full-spanning structures of about one meter in height will create the most preferred coho salmon rearing habitat. It is crucial that sufficient cover/scour logs and/or boulders be placed in pools created by full-spanning structures. This will maintain adequate pool depth and volume over time. Results suggest the importance of concentrating a variety of structures in each reach of stream to provide a complexity of spawning and rearing habitats. Complexity ensures adequate habitats exist for each species' life stages at various flow levels. The use of natural materials (wood and boulders) is more aesthetically pleasing, less costly, longer lasting, and creates more and better habitat conditions than unnatural materials (gabions).

2. Stream type and size—Regarding what streams should be rehabilitated, stream stability and size play an important role. Results suggest that low gradient streams dominated by bedrock bottoms and silty/clay banks that were recently destabilized are not good candidates for rehabilitation. Although rehabilitation has benefited salmonids in all stream sizes, structures installed in larger 5th and 6th order streams (11-18 meters in width) create the most preferred habitat and potential salmonid production. Thus, if the benefit/cost ratio is the primary consideration, work should be concentrated in these larger streams.

3. Riparian management—The management of riparian zones for optimum numbers of mature conifers is the least costly long-term method, of rehabilitating our streams. Under ideal conditions, the Upper Elk project needed 11 conifers per acre to reconstruct a channel where large woody debris was essentially absent. These trees were felled, bucked, yarded and secured in position to recreate conditions that probably existed prior to stream cleaning (an undisturbed channel flowing through a mature riparian zone). The main question is how many more trees (in addition to the 11 conifers per acre) would be needed in a riparian zone to continuously provide optimum habitat conditions over time? Our data suggest that the conifers found in a mature riparian zone (for example, Andrus and Froehlich 1987 found 51 mature conifers per acre in a 94-year riparian stand) might be needed to continually restructure a channel for optimum salmonid production. The additional 41 conifers would be needed to account for trees that fall outside the channel, for those that land in the channel but do not effect instream conditions, and for those needed over time for continual replenishment. An economic evaluation on Elk Creek and the Nestucca River is being conducted to see if this type of management would be cost effective. We recommend that silvicultural practices be applied to our currently understocked riparian areas to provide sufficient present and future mature conifers for large woody debris input.

4. Monitoring—Long-term evaluations of selected rehabilitation projects should continue in order to provide the physical, biological and economic data necessary for accurate project assessment.

VI. Conclusions

Based on our findings over the last eight years from evaluations, stream rehabilitation work seems to have achieved structural, habitat, biological, and economic success. The removal of large structural elements from past forest management practices caused most channels to downcut and straighten and loose their capability to support optimum salmonid populations. The restructuring of degraded stream reaches appears to have reversed this trend in treated areas, creating significant increases in preferred salmonid habitat.

Results of monitoring completed rehabilitation projects in Salem, Coos Bay, and Medford BLM districts indicates physical structural success has been achieved. The high

percentage (95 percent) of structures still providing sufficient habitat shows that techniques are now available to install and secure stable functional structures.

In terms of salmonid habitat, the results of our evaluations show that structures increased gravel substrate, instream cover, pool habitat, total usable habitat, and water volume. All of these are necessary components of preferred salmonid habitat.

Although all streams have benefited to varying degrees from rehabilitation, our results show that treating stream reaches dominated by unstable, silty/clay banks, bedrock, and silt bottoms with low inherent stream productivity appears to be unpractical and not economically justified.

All projects were initiated to improve coho salmon habitat and populations primarily. However, the resulting changes in habitat seem to have had no negative impacts on other salmonids. In fact, all anadromous salmonids have benefited to varying degrees from the addition of instream structures. Most rehabilitation reaches have shown either measured or estimated increases in both summer rearing juveniles and returning adults. The rehabilitation of streams improves more than salmonid habitat. Evaluations show structures dramatically increase water storage capacity and cause channel aggradation, thereby helping to reestablish riparian vegetation. In addition, increased wild production can replace hatchery supplementation and help maintain a high level of genetic diversity in wild anadromous fish stocks.

As indicated by the economic evaluations of individual and all 15 projects combined, the benefits of stream rehabilitation are on the average three times greater than the costs over a 20-year period.

Based on our findings, the best long-term and probably the least costly method of rehabilitating our streams is through an aggressive riparian management policy that provides a buffer zone capable of growing optimum numbers of all sizes of conifers along all streams used by salmonids. This type of management plan is especially important for maintaining and increasing salmonid productivity as only about one-third of the anadromous fish producing areas of our streams can be effectively treated with instream structures.

VII. Published Reports from Project Evaluations and Text References

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VIII. Appendices

East Fork Lobster Creek Project (1981)

East Fork Lobster Creek (EFLC), a fifth order stream draining 3,600 acres, was the first project constructed in the Salem District (other than primarily for fish passage) specifically to improve instream habitat conditions. The project was completed in the summer of 1981 at a cost of $20,000 (Table 1). Initiated to improve coho salmon spawning and summer rearing habitat, EFLC project treated 30 percent (500 meters) of a 1.6-kilometer reach. This project has been intensively monitored for changes in instream habitat conditions and juvenile and adult salmonid populations for seven years (Table 2). East Fork Lobster Creek, along with upper Lobster Creek, is part of a 6-year study started in the 1987-88 winter season by Oregon Department of Fish and Game to determine smolt output in conjunction with stream rehabilitation.

A total of 45 structures (15 constructed of gabions, 26 of boulders, and 4 from a combination of wood and boulders) were installed using manual labor and a medium-sized track-mounted caterpillar tractor. Most structures were full-spanning dam types, with the remainder consisting of boulder groupings and deflectors (Table 3). Full-spanning structures were installed mostly in a "V" shape, while boulders were in tight clusters. Gabion structures were secured by cables, rebar, and entrenched into the banks. All are functioning as planned, although two structures have experienced minor bank cutting (Table 4). In the winter of 1987-88, most gabion structures (12 of 15) experienced deterioration of the top face.

Habitat—The installation of structures changed and increased all habitat types, except high gradient riffles which decreased (Table 5). Although structures substantially increased summer rearing and spawning habitat (House, in press), the major limiting factor in EFLC is (and was) winter habitat. However, further studies on EFLC (Phillips 1986 and ODFW, unpublished data) revealed that treatment increased winter habitat by creating 914 m^2 of dammed and backwater pools and secondary channel habitat.

Spawning—Structures substantially increased spawning areas. From 1981 to 1989, 53 percent of the coho salmon, 64 percent of the steelhead, and 47 percent of the chinook salmon spawned in areas associated with structures (Table EF-1). Total use by these fish ranged from 3.1 to 7.6 redds per structure.

The number of hatchery coho adults straying into EFLC has not changed, averaging 33 fish prior to treatment (1981-83) and 31 fish after (1984-88). However, the ratio of wild to hatchery adult coho salmon returning to EFLC increased from 63 percent wild in pre-treatment years to 84 percent wild in post-treatment years (Table EF-2). Wild coho salmon escapement (redds completed after December 15th), similar in EFLC and control reaches in pre-treatment years, increased fivefold after treatment (Table EF-2), while controls remained relatively stable.

Juveniles—To determine salmonid population changes within the treated reach and at treated sites, a minimum of ten stations (five treated and five controls, totalling 305 meters) are being sampled annually. In most years additional sampling has been conducted at control sites to determine better estimates of total salmonid juveniles. While both treated and control sites experienced increases in all salmonid species and age classes, salmonid abundances and densities have shown substantially higher increases at treated sites (Table EF-3).

Coho and trout fry and steelhead and cutthroat parr have increased 3.7, 2.8, 2.2 times, and 66 percent, respectively, over pre-treatment levels. In the 6 years following treatment, salmonid juvenile populations increased dramatically in the one-mile reach of EFLC (Tables 6 and EF-4).

Production —Based on increases in wild adult returns compared to control stream reaches and increases in pre-smolt populations, there is good evidence that EFLC project has dramatically increased coho salmon production and ocean harvest from this drainage. The project appears to have produced an estimated thirteenfold (20 to 262) increase in adults, with an average annual catch (at 69 percent harvest) of 181 coho (Table EF-5). Steelhead have not shown such dramatic increases as coho salmon. Based on increased numbers of wild redds, post-project adults possibly increased an average of 10-12 steelhead, or an annual catch of around 4 steelhead. Increases in cutthroat parr probably account for an overall increase of 26 adults, producing a catch of 6 sea-run cutthroat annually. Since 1983, this project has produced an average annual value of around $3,613 and increased catches of coho salmon, steelhead and cutthroat trout. As of 1985, a total value of $11,239 can be attributed to the project. If EFLC structures were constructed of boulders instead of gabions, the total cost would have probably been reduced by 2/3 to approximately $6,600. The net species value in 1985 alone was $7,232, more than 1/3 the cost of the original project. These increases were accrued by treating only 30 percent of the project reach. A far greater return might be expected if overwinter habitat, the main limiting factor in EFLC, was substantially increased.

Table EF-1. Use of structures by salmonids in E.F. Lobster Creek, 1981-88

	Coho		Steelhead		Chinook	
Years	Total Redds	Redds Assoc. with Structures	Total Redds	Redds Assoc. with Structures	Total Redds	Redds Assoc. with Structures
1981-82	50	27	79	63	0	0
1982-83	58	38	59	35	0	0
1983-84	24	17	105	75	0	0
1984-85	98	52	63	41	6	6
1985-86	268	121	37	16	3	2
1986-87	125	67	43	19	4	1
1987-88	82	48	22	7	2	2
1988-89	137	77	21	18	76	32
Total	842	447	429	274	91	43

	Number of Redds per structure (24 structures)1/		
	Coho	Steelhead	Chinook
1981-82	1.1	2.6	–
1982-83	1.6	1.5	–
1983-84	0.7	3.1	–
1984-85	2.2	1.7	1.0
1985-86	5.0	0.7	0.5
1986-87	2.8	1.8	0.7
1987-88	2.0	0.3	0.3
1988-89	3.2	0.8	3.6

1/Only six usable structures for chinook, except in the 1988-89 season when nine structures were used.

Table EF-2. Differences in coho salmon and steelhead spawning (redds per 1.6 kilometers) in E.F. Lobster Creek and control reaches in the upper Lobster Creek drainage, 1981-88

	E.F. Lobster Creek				Control reaches1/	
	Coho		Steelhead		Coho	
Year	Total Redds	Wild Redds	Total Redds	Wild Redds	Total Redds	Wild Redds
1981-82	50	12 (24%)	91*	20 (22%)	12	3 (25%)
1982-83	58	31 (53%)	63*	6 (10%)	7	5 (71%)
1983-84	24	6 (25%)	179*	15 (8%)	3	0 (0%)
1984-85	98	76 (78%)	67*	18 (27%)	16	7 (44%)
1985-86	268	219 (82%)	20	17 (85%)	56	54 (96%)
1986-87	125	114 (91%)	24	20 (83%)	27	27 (100%)
1987-88	82	74 (90%)	22	8 (36%)	14	10 (71%)
1988-89	137	108 (79%)	21	12 (57%)	17	14 (82%)

*Surplus hatchery steelhead were released downstream in main Lobster Creek.

1/In control reaches, the distance surveyed ranged from 2.4 to 5.4 kilometers per year.

Table EF-3. Differences in salmonid populations, densities, and biomass between treated and control sites before and after treatment E.F. Lobster Creek, 1981-1988

	Pre (1981)		Post (1982-88)	
	Treated	Controls	Treated	Controls
Coho numbers	324	377	1,507	519
Coho/m^2	0.43	0.47	1.18	0.62
Coho/m^3	3.16	2.79	4.09	2.26
Trout numbers	86	110	369	269
Trout/m^2	0.11	0.14	0.30	0.32
Steelhead (1+) numbers	26	39	74	60
Steelhead/m^2	0.03	0.05	0.06	0.07
Cutthroat (1+) numbers	58	43	91	62
Cutthroat/m^2	0.08	0.05	0.07	0.07
Biomass (g/m^2)	2.8	3.3	5.2	4.5
Surface area (m^2)	757	796	1,282	838
Water volume (m^3)	103	135	369	231

Table EF-4. Estimated salmonid populations in 1.6 kilometers of E.F. Lobster Creek, 1981-88

	Total numbers				
Year	Coho young	Trout fry	Steelhead parr	Cutthroat parr	
1981	4,150	2,670	600	890	Pre
1982	5,940	8,950	870	1,520	Post
1983	8,140	7,020	1,960	1,630	
1984	4,140	4,560	2,170	1,170	
1985	12,150	6,800	2,160	1,820	
1986	16,900	3,180	1,390	1,090	
1987	17,430	2,600	610	1,230	
1988	11,800	7,570	290	730	

Table EF-5. Estimated number of smolts, adults and coho salmon produced in E.F. Lobster Creek, 1979-1987

Brood Year	Pre-smolts	Estimated Smolts	Smolt to Adult Survival1/	Adults Total	Produced2/ Project	Ocean1/ Harvest	Wild Escapement Total3/	Corrected4/	Adjusted5/ Ocean Harvest (69%)	
1978-79	–	906	0.075	68	–	0.763	16 (81-82)	4	12	
1979-80	–	2,140	0.043	92	–	0.553	41 (82-88)	6	9	Pre
1980-81	4,150	725	0.040	29	–	0.725	8 (83-84)	8	20	
1981-82	5,940	2,133	0.060	128	117	0.185	104 (84-85)	95	81	
1982-83	8,140	8,580	0.050	429	322	0.307	297 (85-86)	223	222	
1983-84	4,140	3,344	0.064	214	163	0.282	154 (86-87)	117	112	Post
1984-85	12,150	9,673	0.055	532	463	0.810*	101 (87-88)	88	319	
1985-86	16,900	–	–	317	246	0.536	147 (88-89)	114	170	
1986-87	17,430									
1987-88	11,800									

– No data.

1/ODFW OPI estimate except 1985, where * was derived from private hatchery harvest ratios.

2/Adults produced were determined by dividing the wild escapement by the reciprocal of the yearly projected ocean harvest.

3/Actual wild escapement (redds completed after 12/15) was determined by dividing total redds by 1.7 redds per female and a sex ratio of 1.3 males to females.

4/Corrected wild escapement was determined by reducing the pre-project (1981-83) years (EFLC drew coho that would have spawned in other sections of Lobster Creek) to the average counts observed in control sections of Lobster Creek during pre and post-project years and in 1984-88 years to account for increased escapement in control sections of Lobster Creek.

5/Projected catch was determined by multiplying total adults produced each year by an annual harvest rate of 69 percent.

Tobe Creek Project (1982)

The Tobe Creek Project was completed in 1982 at a cost of $15,800 and treated 11 percent (175 meters) of a 1.6-kilometer reach in a 2,290-acre drainage (Table 1). This project was initiated to improve coho salmon summer rearing and spawning habitat in a reach of stream previously clear-cut and cleaned in the early 1960s. Pre and post monitoring of the project was conducted over a 3-4 year period (Table 2) and most results were described in House and Boehne (1986). A total of 20 gabion structures (at 5 sites) were installed, mainly as full-spanning "V" shaped dams (Table 3). All structures were secured by cables and rebar and entrenched into the banks. All are currently functioning as planned, with no damage (Table 4). As of the winter of 1987-88, a few gabion tops are beginning to deteriorate.

Habitat—Pool habitat increased 892 m^2 by 1987 (Table 5). Riffle habitat had decreased 46 percent, and glides and rapids were not found in treated sites (Table T-1). In treated sites, bottom substrate changed from a predominately boulder, cobble/rubble layer (75 percent) to mainly gravel (Table T-1). In terms of potential types of fish cover, treated sites showed large increases in all types, but especially undercut banks (elevenfold), deep pool (fifty-fourfold) and woody cover, large woody edge, and gabion edge which increased substantially from zero (Table T-2). During the same period, control sites gained and lost accumulations of woody debris which caused major shifts in quantities of woody cover, deep pool and boulder edge.

Spawning—Spawning habitat increased by 149 m^2. This increase at treated sites was responsible for annual gains of 13 coho salmon and 23 steelhead redds (Table 6).

Juveniles—Overall salmonid numbers showed modest increases. Populations increased by 143 coho and 32 trout fry, and 11 steelhead and 6 cutthroat parr (Table 6). At control sites, overall biomass decreased 16 percent, coho fry 31 percent, and trout fry 33 percent, while steelhead parr increased 40 percent (Table T-1). Treated sites registered gains of 16 percent in biomass, 100 percent in coho fry, 37 percent in trout fry, and 70 percent in steelhead parr.

Production—Structures did not create large amounts of preferred habitat for coho salmon due to the small stream size. Consequently, the increased number of salmonid juveniles did not translate into a high annual value for a single structure. Based on this increase, the projected catch produced an annual value of $31 for each structure placed in Tobe Creek (Table 7). The average cost of installing a structure was $700.

Table T-1. Changes in habitat and salmonid populations after treating a 1,340-meter reach of the Tobe Creek, 1982-84

Variables	Before (1982) Treated	Before (1982) Untreated	After (1983-84) Treated	After (1983-84) Untreated
Habitat				
Surface area (m^2/100m)	329	273	492	426
Water volume (m^3/100m)	28	27	116	91
Pool (%)	12	13	96	10
Glide (%)	30	17	0	7
Riffle (%)	50	50	4	63
Rapid (%)	8	20	0	20
Bottom substrate (%)				
Bedrock	5	0	0	5
Boulders	20	20	10	25
Cobble/rubble	55	50	20	30
Gravel	15	25	50	30
Fines	5	5	20	10
Spawning gravel (m^2/100m)	4	0	102	0
Fish				
Coho fry (Total #/100m)	98	104	192	72
No/m^2	0.29	0.38	0.34	0.17
No/m^3	3.42	3.91	1.53	1.05
Trout (Total #/100m)	57	73	78	49
No/m^2	0.17	0.27	0.14	0.11
1+ Steelhead (Total #/100m)	10	9	17	13
No/m^2	0.03	0.03	0.03	0.05
1+ Cutthroat (Total #/100m)	0	2	4	<1
No/m^2	0	0.01	0.01	<0.01
Salmonid biomass (g)	798	540	926	456

Table T-2. Changes in cover factors after treating Tobe Creek, 1982-84

Cover factors	1982 (Pre) Treated	1982 (Pre) Control	1983 (Post) Treated	1983 (Post) Control	1984 (Post) Treated	1984 (Post) Control
Turbulence (m^2/100m)	1.1	3.5	2.9	22.6	7.2	15.0
Undercut bank (m^2/100m)	0.3	0.3	5.1	0.5	2.6	2.0
Woody cover (m^2/100m)	0.0	1.8	0.9	14.3	2.6	1.0
Overhanging veg. (m^2/100m)	3.3	3.1	5.4	0.8	7.0	0.4
Deep pool* (m^2/100m)	0.3	3.5	21.0	9.1	11.9	1.0
Boulder edge (m/100m)	62	59	146	156	189	779
Large woody edge (m/100m)	0	12	10	7	25	7
Gabion edge (m/100m)	0	0	184	0	191	0
Bottom ledge (m/100m)	0	0	0	0	0	0

*Greater than 0.45 meter in depth.

Upper Lobster Creek Project (1982)

Upper Lobster Creek Project was completed in the summer of 1982 at a cost of $8,000. This project was initiated to improve a 91-meter section of stream cleaned of a log-jam in the mid-1960's (Table 1). For around 20 years, this section of stream had not changed physically, being dominated by a riffle flowing mostly over cobble/rubble material. Monitoring was conducted one year prior to treatment and two years after treatment (Table 2). A total of seven gabion full-spanning dam structures, one boulder deflector, 9 meters of bank rip rapping, and a high flow secondary channel were constructed at this site (Table 3). All structures are functioning as planned (Table 4).

Habitat—Surface area nearly doubled and water volume increased threefold after treatment (Table UL-1). Pool and glide habitat increased from zero to 573 m^2. Bottom substrate changed with cobble/rubble halved, fines increasing fivefold, and gravels remaining the same. Available spawning area increased fourfold from an estimated 8 m^2 to 33 m^2.

Spawning—Only one redd was recorded in the 1981-82 spawning season, whereas 12 redds (1 coho and 11 steelhead) were recorded following treatment in the 1982-83 season.

Fish—Salmonid biomass, numbers, and densities increased substantially after treatment total biomass increased fourfold, coho fry and cutthroat yearlings doubled, and trout (age 0) and yearling steelhead increased fivefold (Table UL-1).

Table UL-1. Changes in habitat and salmonid populations after treating a 91-meter section of upper Lobster Creek, 1982-84

Variables	Before (1982)	After (1983-84)
Habitat		
Surface area (m^2)	446	721
Water volume (m^3)	45	155
Pool area (m^2)	0	311
Glide area (m^2)	0	262
Riffle area (m^2)	446	148
Substrate		
Boulders (%)	4	4
Cobble/rubble (%)	51	25
Gravels (%)	40	44
Fines (%)	6	27
Spawning gravel (m^2)	8	33
Fish		
Coho fry (Total #)	38	87
No/m^2	0.08	0.12
No/m^3	0.84	0.56
Trout (Total #)	86	432
No/m^2	0.19	0.60
1+ Steelhead (Total #)	17	40
No/m^2	0.04	0.05
1+ Cutthroat (Total #)	5	23
No/m^2	0.01	0.03
Salmonid biomass (g)	355	1,496

South Fork Lobster Creek Project (1982)

During the summer of 1981, a 914-meter reach of South Fork Lobster Creek (SFLC) was severely impacted as a result of a timber sale and log jam removal. This sale eliminated the old-growth riparian zone, leaving no buffer, while the removal of the log jam destabilized the channel by yarding the jam material downstream to the nearest road. The channel was left with little or no instream structure and no chance for future recruitment of structure. During the summer of 1982, a 152-meter section of the unstable reach was monitored for habitat conditions and fish populations prior to treatment. Later that summer, the stream reach was treated using 65 logs, rootwads, and boulders located within the existing flood plain. A total of 50 large conifers, 11 rootwads, and 4 large boulders were placed in the low flow channel as dams (1), deflectors (49), and cover/scour (15) structures. All structures were diagonally shaped, with the exception of rootwads and boulders.

Because structures were installed in a destabilized flood plain, the low flow channel was free to move back and forth, which eventually left some structures isolated out of the main low flow channel. Fourteen of the 50 (28 percent) large woody boles were out of the channel, with 19 intervening the channel by 1/3 of its width, 16 by 2/3 and 1 full spanning. Three of 11 (27 percent) rootwads were out of the channel, with 6 intervening by 1/3 and 2 by 2/3.

Habitat—In 1984, 61 meters of the 152-meter previously monitored section was again measured for habitat changes. This typical 61-meter section was treated with five deflector logs and one boulder. In this section, surface area decreased slightly, water volume almost doubled, pool area increased from zero to 36 percent, and average and maximum depths more than doubled (Table SF-1). Newly added woody material in the entire 914-meter reach created 9 plunge, 24 lateral scour, and 9 backwater pools totalling 63 m^2 of habitat. These structures also created five secondary channels totalling 26 m^2 of habitat.

Fish—In the 61-meter stream section, salmonids (probably mostly cutthroat, although some steelhead and coho salmon have occasionally spawned in this reach) increased twenty-fourfold in number, with 1+ cutthroat increasing tenfold and biomass fivefold (Table SF-1).

Although this project experienced the highest rate of structure failure, the remaining successful structures changed and provided better habitat for older rearing cutthroat.

Table SF-1. Changes in physical components and salmonid populations after treating a 61-meter section of S.F. Lobster Creek, 1983-84

	Study Site (200')	
Variables	**Pre (1983)**	**Post (1984)**
Surface area (m^2)	121	110
Water volume (m^3)	7.0	12.1
Pool area (m^2)	0	40
Riffle area (m^2)	121	70
Max. depth (cm)	20.1	45.7
Avg. depth (cm)	5.8	12.2
Substrate (%)		
Boulder	2	7
Cobble/rubble	57	30
Gravels	37	48
Fines	4	15
Fish		
Total salmonids	6	146
Trout (0+)	3	115
Cutthroat (1+)	3	31
Trout/m^2	0.02	1.05
Cutthroat/m^2	0.02	0.28
Biomass (g)	89	430
Grams/m^2	0.73	3.90

Little Lobster Creek Project (1986)

Little Lobster Creek project was initiated to improve rearing conditions for coho salmon and steelhead and reduce the amount of bedrock substrate. Preliminary surveys revealed extremely low densities of all rearing salmonids, but adequate adult escapement, especially for coho salmon. The project, costing $13,000, treated 585 meters (60 percent) of a 968-meter low gradient reach of stream dominated by vertical banks composed of clay and sand/silt and a bedrock bottom (Table 1). This section of stream has been monitored for changes in habitat conditions, juvenile and adult salmonid populations, and structural changes for up to 6 years - 4 pre and 2 post (Table 2). Results of project monitoring are described in more detail in Monthey, House, and Hardin (in prep.). A total of 142 structures (135 constructed of boulders and 7 of wood and boulders) were installed using a medium-sized track-mounted cat. Most structures were tight boulder groupings, with the remainder full-spanning structures in diagonal (16), "V" (7), semi-circle (5), and perpendicular (2) shapes (Table 3).

Most structures are functioning as planned (139); however, three are partially broken out and are repairable nonfunctional (Table 4).

Habitat—Stream habitat prior to treatment was dominated by trench pools (34 percent) and low gradient riffles (31 percent) (Table LLC-1). Following treatment, dominant habitats included dammed pools created by rehabilitation structures (28 percent), low gradient riffles (31 percent), and glides (19 percent). This is the only project that has experienced a loss in pool habitat, total habitat, and water volume. The high numbers of boulder deflectors decreased overall channel width while full-spanning structures silted-in behind, reducing pool area and bedrock substrate. Boulder deflectors installed in riffle areas were able to decrease bedrock and increase available gravel (Table LLC-2).

Juveniles—Coho fry were the only salmonid that responded to treatment. Although overall pool habitat and coho adult spawners decreased (Table 6), coho fry densities in pools and glides doubled over pre-treatment levels. The increase in coho densities produced an overall gain of 597 coho fry after rehabilitation of the study area (LLC-3). Steelhead and cutthroat trout were found in low numbers before and after treatment.

Table LLC-1. Habitat changes after treating 585 meters of a 968-meter section of Little Lobster Creek, 1986-87

	Pre (1986)				Post (1987)			
Habitat Type	Number	Total Length (m)	Surface Area (m²)	Water Volume (m³)	Numbers	Total Length (m)	Surface Area (m²)	Water Volume (m³)
Pool								
Trench	24	309	1,898	606	4	26	129	48
Lateral scour	4	20	204	92	17	150	690	214
Dammed	5	99	815	377	16	225	1,360	495
Plunge	2	12	64	17	3	8	47	17
Backwater	2	12	60	11	18	76	160	32
Sec. channel	1	6	12	4	4	33	48	5
Total	38	458	3,053	1,107	62	518	2,434	811
Gilde	8	157	763	174	13	162	898	232
Riffle								
Low gradient	8	220	1,719	215	25	335	1,497	166
Sec. channel	1	7	12	1	2	14	15	2
Grand Total	**75**	**842**	**5,547**	**1,497**	**101**	**1,029**	**4,844**	**1,211**

Table LLC-2. Bottom substrate before and after treatment of Little Lobster Creek

Habitat	Dominant Substrate	Before (%)	After (%)
Pools	Bedrock	66	8
	Sand/silt	31	82
	Gravel	3	9
	Boulder	–	1
Riffles	Bedrock	47	30
	Sand/silt	–	8
	Gravel	28	53
	Cobble/rubble	25	9
Glides	Bedrock	22	18
	Sand/silt	12	47
	Gravel	42	31
	Rubble	24	4

Table LLC-3. Changes in coho salmon population and densities before (1984-86) and after (1987-88) rehabilitation in Little Lobster Creek

	Pre (1984-86)		Post (1987-88)	
Habitats	N/m²	Population	N/m²	Population
Pool	0.16	488	0.35	852
Glide	0.03	53	0.11	165
Riffle	0.12	92	0.27	243
Total		663		1,260

"J" Line Creek Project (1987)

"J" Line Creek, a small unnamed tributary (1,035 acres) located in upper Lobster Creek, was severely impacted by the 1964 100-year flood, logjam removals, and stream cleaning from the early 1950s through the mid-1960s. The end result was a relatively straight channel depleted of structure with little pool habitat. In the summer of 1987, a 396-meter section (15 percent) of a 2,576-meter reach was treated with 43 main channel structures at a cost of $2,400 (Table 1). The primary purpose of the project was to improve summer and winter rearing for juvenile coho salmon and steelhead. This project has been monitored for habitat, fish, and structural changes during four pre-treatment and two post-treatment survey years (Table 2). Structures were installed using a track-mounted excavator.

The treatment, which included installing 13 dam (full-spanning), 11 deflectors, 5 cover/scour structures and 15 feet of riprap bank stabilization (Table 3), consisted mostly of offsite boulder and onsite large woody materials. Structures were installed in "V" (2), diagonal (27), semi-circle (7), and boulder grouping (7) shapes. Of the 29 structures installed in 1987, 26 were fully functional, 2 were damaged functional, and 1 repairable nonfunctional after a 5-year event the following winter (Table 4).

Habitat—After treatment, surface area and water volume increased 15 percent and 43 percent, respectively (Table JL-1). Pool habitat tripled, while glides and high gradient riffles were less than half as prevalent. Dam and lateral scour pools showed the largest increases. Large wood increased in diameter and doubled in total length and number of pieces after treatment.

Spawning—Spawning ground counts, conducted since 1981 in this reach, showed pre-project adult returns averaging four coho and six steelhead redds per spawning season (Table JL-2). In the 1987-88 season, nine coho and no steelhead redds were counted in this reach.

Juveniles—Coho juveniles were the only salmonid that showed favorable gains after treatment. Coho juvenile numbers nearly doubled and average densities per pool were higher than any year prior to treatment (Table JL-2). In the post- treatment year, steelhead and cutthroat yearling numbers and densities were on the low end of the range for pre-treatment years.

Table JL-1. Changes in habitat conditions after treating a 396-meter section of "J" Line Creek, 1987-88

	Pre (1987)				Post (1988)			
Habitat Types	Number	Total Length (m)	Surface Area (m^2)	Water Volume (m^3)	Number	Total Length (m)	Surface Area (m^2)	Water Volume (m^3)
Pools								
Lateral scour	6	39	101	22	9	56	169	52
Plunge1/	4	14	45	12	10	24	65	20
Backwater	2	5	9	1	9	28	57	8
Dammed1/	1	14	42	13	8	69	288	81
Glides	9	83	214	40	6	43	145	30
Riffles								
Low gradient	10	133	331	40	13	146	423	39
High gradient	3	109	316	39	3	22	69	9
Total	35	392	1,058	167	58	388	1,216	238
Large wood								
Number of pieces		18				36		
Total length (ft)		174				388		
Average diameter (ft)		1.5				2.0		

1/Two pools totaling 60 m2 (18.3 m3) were created by two gabion installed in 1986 (habitat was previously a low gradient riffle).

Table JL-2. Salmonid use before and after treating a 396-meter section of "J" line creek, 1981-87

Fish Species		Pre (1981-83, 85)	Post (1988)
Coho			
Number for 396 m	Average	820	1,400
	Range	322-1,274	—
Number/100m of pool	Average	552	950
	Range	73-956	—
Number/m^2 of pool	Average	1.60	2.44
	Range	0.64-2.28	—
Steelhead (1+)			
Number for 396 m	Average	45	37
	Range	32-63	—
Number/m^2	Average	0.05	0.03
	Range	0.03-0.06	—
Cutthroat (1+)			
Number for 396 m	Average	36	23
	Range	21-61	—
Number/m^2	Average	0.07	0.04
	Range	0.05-0.10	—
Salmonid biomass (g/m^2)	Average	3.9	5.1
	Range	3.1-5.6	—
Redds (number/396 m) Coho	Average	4	9
	Range	0-8	—
Steelhead	Average	6	0
	Range	0-15	—

Lobster Creek Project (1987)

The Lobster Creek Project, completed the summer of 1987, was part of an ongoing program to rehabilitate the Upper Lobster Creek drainage. Upper Lobster Creek, a sixth order stream draining approximately 11,300 acres, was severely impacted by forest management activities and the 1964 100-year flood. Because of these impacts and the administering of 98 percent of the drainage, the Salem District has conducted intensive evaluations since 1980 (the first basin wide inventory), with most results described in House and Boehne's (1987) report "Upper Lobster Creek Habitat and Fish Use Analysis." This report assessed the watershed, its impacts, habitat and water quality conditions, fish use, habitat improvement priorities and evaluated of completed projects in this drainage. Currently, the Salem District Alsea Resource Area has completed two projects in E.F. Lobster, one in S.F. Lobster, two in upper mainstem Lobster, one in "J" line, and one in the lower mainstem Lobster Creek. After completion of ODFW's 6-year smolt output study, more work will be scheduled in this drainage, specifically to improve overwintering habitat.

The Lobster Creek Project was initiated to improve winter and summer habitat for coho salmon and steelhead and, to a lesser degree, to disperse spawning habitat for chinook and coho salmon. This project, costing $10,600, treated 488 meters (40 percent) of a 1,219-meter reach of stream (Table 1). Monitoring included habitat, juvenile, and structural surveys conducted in both pre and post years (Table 2). A total of 37 structures, installed with a track mounted excavator, were placed in the main channel. Most structures were full-spanning boulder dams (23) with the remainder partial spanning deflectors (5) and cover structures (Table 3). Structures were constructed mostly of off-site boulders, (28) combinations of onsite large wood, and on and off-site boulders (9). Full-spanning structures were installed as diagonals (12), semicircles (8), "V"s (1), and perpendiculars (2), with partial spanning structures placed in single or loose boulder groupings.

Habitat—Treating 40 percent of Lobster Creek increased total surface area by 25 percent and water volume by 54 percent (Table LC-1). More specifically, pool surface area and water volume doubled, increasing 3,215 m^2 and 1,648 m^3, respectively.

The number of pools increased from 32 to 66. Glide habitat, however, decreased by 1,210 m^2 or 61 percent, and secondary channel habitat increased from zero to 430 m^2. Large wood increased from 23 to 60 pieces, with a 741 foot increase in total length (Table LC-1).

Juveniles—Coho salmon and trout juveniles were the only salmonids that increased substantially after treatment. Coho juvenile densities were 4 times greater resulting in an overall population increase of almost sixfold in the post-treatment years (Table LC-2). Trout fry also increased, with densities doubling and populations tripling over pre-treatment levels. Steelhead yearling densities and numbers were substantially lower in the post-treatment year. However, this reduction was found in all other Lobster Creek streams in 1988. Cutthroat trout densities and numbers were similar in pre and post-treatment years.

Table LC-1. Habitat changes after treating 1,219 meters of Lobster Creek, 1987-1988

	Pre (1987)				Post (1988)			
Habitat Types	Number	Total Length (m)	Surface Area (m^2)	Water Volume (m^3)	Number	Total Length (m)	Surface Area (m^2)	Water Volume (m^3)
Pools								
Lateral scour	12	121	987	511	10	90	638	408
Backwater	13	57	138	33	20	93	216	56
Trench	5	57	349	227	5	50	250	143
Dammed	–	–	–	–	18	346	3,322	1,692
Plunge1/	2	6	38	16	12	44	261	118
Secondary channel	–	–	–	–	1	8	40	18
Total	32	241	1,512	787	66	631	4,727	2,435
Glide	14	130	1,918	810	6	83	708	316
Riffles								
Low gradient	20	380	3,438	961	20	305	3,854	945
High gradient*	16	460	3,751	999	26	541	4,650	1,735
Secondary channel	–	–	–	–	8	127	390	61
Grand Total	82	1,211	10,619	3,557	126	1,687	13,269	5,492
Large wood								
Number of pieces		23				60		
Average diameter (ft)		1.7				2.3		
Total length		440				1,181		

1/The two plunge pools recorded in the pre-project year were created by two boulder dams installed the summer of 1984.

Table LC-2. Changes in salmonid populations and densities before and after treating Lobster Creek, 1983, 1984, and 1988

	Pre		Post
Fish	1983	1984	1988
Total coho	1,670	899	8,505
Coho/m^2 (pool)	0.48	0.26	1.46
Total trout	881	1,279	2,857
Trout/m^2	0.08	0.11	0.19
Total steelhead (1+)	1,046	1,628	392
Steelhead/m	0.09	0.14	0.03
Total cutthroat (1+)	177	465	386
Cutthroat/m^2	0.02	0.04	0.03

Upper Lobster Creek Project (1987)

Upper Lobster Creek Project, finished in 1987, was the second small project completed within a 2-mile stretch of Upper Lobster Creek. No more work will be conducted in this reach until the summer of 1993, since it is the control reach 6-year effort by ODFW to determine changes in smolt outputs after rehabilitation. This project treated 52 meters (35 percent) of a 147-meter section of fifth order stream (average channel width of 19 feet). Completed at a cost of $5,600, this project was initiated to improve coho salmon winter and summer habitat (Table 1). This stretch has been monitored for 5 years (4 pre-treatment), including habitat, juvenile, adult, and structural surveys (Table 2).

A total of 14 structures were installed in the main channel using a track-mounted excavator. Structures included four full-spanning dams, six partial spanning deflectors, and four cover/scour types (Table 3). Structural material consisted mainly of off-site boulders and onsite large wood. Structure shapes were diagonals (7), semi-circles (3), loose boulder groupings, and a rootwad. After a 5-year event in the 1987-88 winter, 10 structures were fully functional, 3 damaged functional, and 1 repairable non-functional.

Habitat—Structures increased the overall surface area 18 percent and doubled pool habitat (ULC-1). Habitat complexity also increased, increasing from 13 to 23 habitat changes. The largest increases occurred in lateral scour, backwater, and secondary channel pools and riffles. Dam pools decreased because all full-spanning structures were damaged and not capable of storing water.

Juveniles—Compared to other salmonids, coho salmon juveniles showed the greatest response to treatment. Their abundance and densities nearly doubled the 4-year average pre-treatment (ULC-2). Although coho increased and cutthroat rose to over 50 percent of the pre-treatment levels, steelhead exhibited a sharp decline.

Table ULC-1. Habitat changes after treating a 147-meter section of upper Lobster Creek, 1987-88

Habitat Types (Numbers)	Pre (1987) Surface Area (m^2)	Post (1988) Surface Area (m^2)
Pools		
Trench	64 (1)	0 (0)
Lateral scour	39 (1)	169 (6)
Plunge	22 (1)	36 (1)
Backwater	12 (1)	99 (8)
Dammed	27 (1)	0 (0)
Secondary channel	0 (0)	36 (1)
Total	164 (5)	340 (16)
Glides	138 (2)	13 (1)
Riffles		
Low gradient	221 (5)	239 (4)
Secondary channel	28 (1)	56 (2)
Grand Total	551 (13)	648 (23)

Table ULC-2. Changes in salmonid populations before and after treating a 147-meter section of upper Lobster Creek, 1983 and 1985-88

	Pre				Post
Fish	**1983**	**1985**	**1986**	**1987**	**1988**
Coho/m	1.07	2.14	2.91	3.58	3.94
Coho/m^2	0.24	0.47	0.64	0.83	0.95
Coho/m^3	0.93	2.31	3.70	3.76	3.56
Trout/m	0.74	0.67	0.26	0.27	0.20
Trout/m^2	0.16	0.15	0.06	0.06	0.05
Steelhead (1+)/m	0.14	0.30	0.15	0.06	0.04
Steelhead/m^2	0.03	0.07	0.03	0.01	0.01
Cutthroat (1+)/m	0.09	0.12	0.06	0.04	0.12
Cutthroat/m^2	0.12	0.03	0.01	0.01	0.03

East Fork Lobster Creek Project (1987)

This work is a continuation of the initial East Fork Lobster Creek project completed in 1981. At a cost of $1,400, nine structures were installed at three sites treating 183 meters of stream (Table 1). Because this treatment included a 31-meter control station used for the 1981 project monitoring, 7 years of pre-treatment juvenile and adult use were available for comparison (Table 2).

Eleven structures, including one off-channel area, were constructed using 80 yd^3 of boulders and 157 feet of large wood. Five structures were full-spanning dam types with the remainder (6) deflectors (Table 3). The structures were constructed of boulders (5) and large wood (6), mostly from offsite materials, and were installed in diagonal (8) and semi-circle (3) shapes.

All structures are functioning as planned; however, one large tree secured by boulders was moved downstream, but is still functional (Table 4).

Habitat—Prior to treatment, the 100-foot study section of stream was a high gradient small boulder and cobble riffle dominated by boulder edge and turbulence cover (EFL-1). After treatment with three boulder dams the amount and type of habitat, cover, and bottom substrate changed appreciably. Water volume increased threefold while surface area increased 18 percent with the entire sections converted into pool habitat. Maximum and average depths doubled and bottom substrate included higher percentages of fines and gravel (Table EFL-1). Available cover changed substantially, to deep pool and overhanging vegetation dominating (young alders were felled into the pools to provide additional salmonid juvenile cover).

Juveniles—A high gradient riffle was changed into a series of three pools which dramatically increased salmonid numbers and biomass (EFL-2). Coho juveniles increased ninefold, trout doubled, and older age steelhead and cutthroat increased 40 percent over the seven years average prior to treatment. Total salmonid biomass almost tripled over the average of seven pre-treatment years. These results show that rehabilitation designed primarily to benefit coho salmon seems to have no detrimental impact on other salmonids.

Table EFL-1. Habitat, instream cover, and bottom characteristics of a 31-meter section of stream before and after treatment 1983-88

Habitat	Pre (1983-87)	Post (1988)
Surface area	153.0 m^2	181.0 m^2
Water volume	19.3 m^3	61.6 m^3
Avg. depth (ft)	0.4	1.1
Max. depth (ft)	1.2	2.0
Cover		
Turbulence (ft^2)	19	29
Undercut banks (ft^2)	8	0
Woody cover (ft^2)	12	0
Overhanging veg. (ft^2)	10	202
Deep pool (ft^2)	0	261
Boulder edge (lin. ft)	219	91
Large woody edge (lin. ft)	>1	5
Bottom substrate (%)		
Large boulder	6	10
Small boulder	41	19
Cobble	23	31
Rubble	18	10
Large gravel	7	11
Small gravel	5	9
Sand	0	5
Silt	0	1

Table EFL-2. Differences in salmonid populations, densities, and biomass before and after treating a 31-meter section of E.F. Lobster Creek, 1981-88

Fish	Pre (1981-87)	Post (1988)
Coho numbers	28	250
Coho/m^2	0.18	1.4
Coho/m^3	1.45	4.1
Trout numbers	49	171
Trout/m^2	0.32	0.9
Steelhead (1+) numbers	14	17
Steelhead/m^2	0.09	0.1
Cutthroat (1+) numbers	11	28
Cutthroat/m^2	0.07	0.2
Total Salmonid biomass (g)	544	1349
Grams/m^2	3.6	7.5

East Beaver Creek Project (1983)

East Beaver Creek, a drainage volcanic in origin with steep landforms highly prone to landslides, has been subjected to numerous floods and debris torrents since initial intensive logging. The largest recorded flood event occurred in 1972, a time when much of the upper drainage had been logged and small draws were left deep in unmerchantable logs and slash. This flood and subsequent stream cleaning completely scoured and removed large woody structure from the upper stream reaches within the drainage. After stream cleaning, high flows flushed out essentially all sediments and gravels. In the early 1980's the channel had downcut to bedrock and stable cobble/rubble and boulder substrate, leaving few pools and virtually no spawning gravels. These conditions were contrary to what was found in the first recorded inventory of upper E. Beaver Creek (1957), which revealed at least two major log jams per mile and a channel consisting of 35 percent gravel, of which 15 percent was considered spawning areas (ODFW, unpublished data).

Detailed inventories conducted in 1983, prior to initial stream rehabilitation, revealed only 13 percent of the channel was pool habitat and less than 1 percent was considered suitable spawning areas. Presently, coho salmon use is low with only an average of two spawning fish per mile and limited juveniles rearing in the upper reach.

In 1983, the first part of a proposed long-term rehabilitation effort, was completed with the installation of 32 gabion and boulder structures. This project, costing $24,600 and treating 304 meters (47 percent) of a 640-meter reach of upper E. Beaver Creek, was designed to improve spawning and summer rearing habitat for coho salmon (Table 1). Monitoring this project by habitat, juvenile and adult fish use, and structural assessments, has occurred over 6 years (Table 2). Most structures were full-spanning dam types constructed mostly of onsite substrate for gabion fill (Table 3). Structure shapes were mainly in "V" configurations (12), but included diagonals (2), semicircles (6), boulder groupings (8) and rootwads (2). This work totaled 822 feet of gabions, 134 feet of boulder structures, 310 feet of side channel, 2 rootwads, and 2 blasted bedrock pools.

Currently, all structures are fully functional, secured with cables and rebar, and entrenched into the bank (Table 4).

Habitat—Significant changes occurred in habitat and bottom substrate after treatment of the 304-meter study section. Pool habitat increased fourfold and gravels doubled (Table EB-1). The largest gain was in dam pools which increased 1,306 m^2 (Table 5). Most pool types increased, while high gradient riffles showed the greatest loss. Cover factors, with the exception of turbulence and overhanging vegetation, all increased substantially from pre-treatment levels (Table EB-2)

Spawning—Spawning ground counts have been conducted on this reach of E. Beaver Creek since 1983. Pre-project (1983-85) returning coho adults averaged only 1 fish and 1 redd, while post-project adults (1986-88) increased to 13 fish and 4 redds (Table EB-3). Steelhead adult use showed greater gains, increasing from 2 redds and 8 observed adults in 1983 to an average of 42 redds and 19 adults between 1984 through 1987. In the fall of 1988, 14 fall chinook salmon adults and four redds were counted in this stream reach.

Juveniles—Substantial increases in biomass, densities, and numbers of summer salmonid juveniles have occurred since treatment. Overall, salmonid biomass increased one to twofold in treated sites while control sites remained constant over a 4-year period (Table EB-4). Pools created by structures showed higher coho juvenile use than pools located downstream and upstream from the treated section and in natural pools within the treated section (EB-5). Higher densities of coho juveniles in 1985 and 1986 were the result of planting 28,000 fry and 30,000 pre-smolts, respectively, in this reach of E. Beaver Creek. Steelhead parr showed basically the same responses as coho juveniles, with numbers in pools and overall abundance and densities higher in the treated sites compared to control sites (EB-6). When comparing specific treated sites, the addition of cover (rootwad) in a trench pool and boulder dams on a rubble riffle dramatically increased all salmonid species and age groups (Table EB-7). Overall, coho, trout, steelhead, and cutthroat showed gains in total numbers after treatment (Table 6).

Production—When comparing actual versus potential numbers of coho and steelhead juveniles, substantial increases in coho numbers might have occurred. Based on habitat changes and optimum seeding, numbers of coho and steelhead juveniles would more than double (Table EB-8). However, overwintering habitat is still the limiting factor in EBC for coho juveniles. Based on available overwintering habitat, which increased sixfold after treatment, this reach is only capable of producing around 1,000 coho smolts, or an increase of around 830 coho smolts after treatment. Because of the high cost and relative small size of gabion structures, the cost/benefit ratio was not favorable for the E. Beaver Creek Project. The annual value, projected from estimated increased juveniles and catch, was $75 per structure (Table 7). The average cost per full-spanning structure was $1,200.

Table EB-1. Changes in habitat and bottom substrate after treating 304 meters of a 640-meter reach of E. Beaver Creek, 1983-84

Variables	Before (1983)		After (1984)	
Habitat				
Surface area (m^2)	2,693		2,675	
Stream length (m)	621		641	
Pools (m^2)				
Backwater (#)	132 (34)		22 (4)	
Trench (#)	91 (4)		50 (1)	
Lateral scour (#)	8 (2)		44 (2)	
Plunge (#)	30 (8)		151 (9)	
Dam (#)	31 (2)		1,337 (20)	
Secondary channel (#)	5 (1)		11 (1)	
Glide (m^2)	24		85	
Riffles (m^2)				
Secondary channel	52		35	
Low gradient	666		329	
High gradient	1,654		611	
	Treated	Untreated	Treated	Untreated
Bottom substrate (%)				
Boulders	16	19	16	21
Cobble/rubble	51	41	16	18
Gravels	18	20	35	39
Fines	4	10	28	12
Bedrock	11	10	5	8

Table EB-2. Changes in habitat cover factors after installing gabion and boulder structures in E. Beaver Creek, 1983-84

	Pre (1983)		Post (1984)	
Factors	Treated	Untreated	Treated	Untreated
Turbulence (m^2/100m)	20	20	3	6
Undercut bank (m^2/100m)	>1	>1	4	>1
Large woody cover (m^2/100m)	0	1	2	>1
Overhanging veg. (m^2/100m)	12	6	4	5
Deep pool (m^2/100m)	24	56	71	18
Boulder edge (m/100m)	33	97	130	172
Large woody edge (m/100m)	0	2	4	>1
Gabion (m/100m)	0	0	30	0
Bottom ledge (m/100m)	1	9	7	7

Table EB-3. Steelhead and coho salmon escapement and redds in 2,100 feet of E. Beaver Creek, 1982-88

Year	Steelhead		Coho		
				Observed Adults	
	Redds	Observed Adults	Redds	Peak	Total
1982–83	2	8	1	2	2
1983–84	61	41	1	1	1
1984–85	44	18	3*	7*	11*
1985–86	28	7	2	6	8
1986–87	35	9	7	5	20
1987–88	11	1	2	6	10
1988-89	11	1	13	6	17

*100 surplus coho salmon adults (50:50 sex ratio) were released upstream from the treated reach, of which two redds, six peak and nine total count were attributable to our counts.

Table EB-4. Changes in salmonid biomass in treated and control sites before and after treatment in E. Beaver Creek, 1983-87

Year	Treated		Control		
	g/m	g/m²	g/m	g/m²	
1983	17.4	2.69	27.5	6.96	Pre
1984	33.4	7.08	30.4	10.81	
1985	42.2	7.75	33.8	6.60	Post
1986	37.0	5.12	21.8	4.92	
1987	23.0	4.42	18.3	4.97	

Table EB-5. Changes in coho juvenile numbers and densities in treated and control pools in E. Beaver Creek, 1983-87

				Rehabilitated reach									
	Downstream control pools			Treated pools			Untreated pools			Upstream control pools			
Year	No/pool	No/m	No/m²	No/pool	No/m	No/m²	No/pool	No/m	No/m²	No/pool	No/m	No/m²	
1983	7.5	0.90	0.20	0.0	0.00	0.00	0.0	0.00	0.00	0.0	0.00	0.00	Pre
1984	–	–	–	1.0	0.06	0.01	0.0	0.00	0.00	0.0	0.00	0.00	
1985	18.5	2.21	0.26	51.1	2.85	0.48	12.7	1.02	0.25	0.0	0.00	0.00	Post
1986	13.5	1.62	0.41	64.8	3.60	0.49	25.0	2.48	0.54	7.8	1.15	0.28	
1987	10.5	1.03	0.29	29.8	1.66	0.35	8.7	0.86	0.21	0.0	0.00	0.00	
1988	3.5	0.43	0.11	10.7	0.70	0.13	0.0	0.00	0.00	0.0	0.0'0	0.0	

Table EB-6. Changes in steelhead parr (1+) numbers and densities in treated and control sites in E. Beaver Creek, 1981-88

				Rehabilitated reach									
	Downstream control pools			Treated pools			Untreated pools			Upstream control pools			
Year	No/pool	No/m	No/m²	No/pool	No/m	No/m²	No/pool	No/m	No/m²	No/pool	No/m	No/m²	
1983	16.0	1.92	0.43	11.5	0.72	0.12	17.3	1.25	0.23	5.6	0.85	0.19	Pre
1984	–	–	–	15.2	1.51	0.28	11.5	0.86	0.17	7.5	0.72	0.21	
1985	15.5	1.11	0.22	16.7	1.27	0.23	14.1	1.08	0.25	6.3	1.11	0.30	Post
1986	6.0	0.65	0.18	13.7	0.91	0.13	15.0	0.94	0.22	7.3	0.41	0.09	
1987	19.0	1.95	0.52	8.8	0.54	0.10	7.0	0.77	0.21	3.3	0.47	0.13	
1988	9.5	1.18	0.29	13.1	0.85	0.16	9.0	0.88	0.27	9.25	1.04	0.32	

Table EB-7. Differences in salmonid numbers and densities by adding rootwad cover in a trench pool and placing boulder dams in a rubble riffle, E. Beaver Creek, 1983-87

	Trench Pool		Rubble Riffle	
Fish	Pre (1983)	Post (1984-87)	Pre (1983)	Post (1984-87)
Coho #'s	0	49	1	147
Coho/m^2	0.00	0.28	>0.01	0.47
Trout (0+) #'s	36	50	90	248
Trout/m^2	0.23	0.28	0.30	0.79
Steelhead (1+) #'s	12	32	41	80
Steelhead/m^2	0.08	0.19	0.14	0.26
Cutthroat (1+) #'s	0	7	2	16
Cutthroat/m^2	0.00	0.04	0.01	0.05

Table EB-8. Changes in coho juveniles and steelhead (1+) after treating a 2,100-foot reach of E. Beaver Creek, 1983-87

	Pre		Post	
Fish	Actual1/	Potential2/	Actual1/	Potential2/
Coho numbers	5	1,113	550	2,751
Steelhead (1+) numbers3/	236		558	

1/Based on sampled densities of coho juveniles in different habitats and projected for total available habitat.

2/Based on densities of 1.5 coho/m^2 of pool, 0.8 coho/m^{2}m glides, and 0.4 coho/m^2 in cobble/boulder riffles for total available habitat.

3/Steelhead were assumed to be fully seeded in pre and post conditions.

Testament Creek Project (1985)

The Testament Creek Project, completed in 1985, consisted of placing cull logs in conjunction with the Rye Bread Timber Sale and falling riparian trees using the District's 3P cutter. At a total cost of $1,200, 15 cull logs (all Douglas-fir) were placed in the stream at logging cable "roads", and 2 fir and 20 large alder trees were felled and bucked along 320 meters of stream (Table 1). This project was experimental in nature, designed to test the feasibility of adding stream structure during a timber sale with a withdrawal buffer running through the middle. Logs yarded into the channel basically formed three log jams, whereas most felled trees bridged the stream within the high water channel. Coho salmon were the primary benefiting species.

Habitat—Habitat and large woody debris were monitored before and after treatment. Additional large woody debris increased pool habitat 58 m², glide habitat 32 m², and secondary channel habitat 44 m²(TC-1). Large woody debris increased by 1,060 feet in length, and by 85 pieces. Inspection indicates that substantial pools were formed during winter flows behind each of the three mini-logjams formed by added woody debris.

Juveniles—The increase in pool habitat translated into a potential 24 percent increase of coho juveniles, or 142 fish.

Table TC-1. Changes in habitat conditions after bucking and yarding cull trees into a 1,050-foot section of Testament Creek, 1985 and 1987

Habitat types	Pre (1985) Numbers	Pre (1985) Surface Area (m²)	Pre (1985) Water Volume (m³)	Post (1987) Numbers	Post (1987) Surface Area (m²)	Post (1987) Water Volume (m³)
Pool						
Lateral scour	11	133	36	4	74	16
Plunge	3	24	8	6	108	23
Trench	1	5	1	–	–	–
Backwater	3	13	1	7	35	4
Dammed	–	–	–	1	16	4
Glides	12	212	45	13	244	43
Riffles						
Low gradient	8	308	34	8	399	60
High gradient	14	421	39	20	496	80
Secondary channel	–	–	–	3	44	5
Total	52	1,116	164	62	1,416	235
Large woody debris						
Total length (m)		119			442	
Avg. diameter (m)		0.48			0.45	
No. pieces		42			127	
Avg. length (m)		2.8			3.5	

Upper Nestucca River Project (1986)

The Upper Nestucca River has been severely impacted by a closely associated road, stream cleaning, and (especially) the failure of Meadow Lake Dam in 1962. These problems straightened and narrowed the channel, scoured the bottom to bedrock and large substrate, and reduced pool habitat with the elimination of large woody structure. House et al. (1988) provide a more detailed analysis of this project and the lower Elk Creek project.

Improvement of the upper section Nestucca River was completed in the summer of 1986 to increase coho salmon summer and winter rearing habitat. This project included the installation of 197 structures in 5.3 miles of stream (Table 1). Approximately 37 percent (1.9 miles) of this reach was treated at a cost of $55,000. In addition to the installation of main channel structures, work included creating and/or reopening nine off-channel areas previously blocked by the debris torrent from the Meadow Lake Dam failure.

Evaluation has included one to two years of pre-habitat, juvenile, and adult surveys and one year of similar post-surveys, including a structural survey (Table 2). Of the 197 structures installed, 84 were constructed of boulders, 44 by large wood, five of rootwads, and 64 a combination of wood and boulders (Table 3). Structures included 82 dams, 9 diversions (for off-channel areas), 42 deflectors, 56 cover, 3 scour, 1 trash, and 4 combination cover/scour. Structure shapes included 13 "V's", 44 diagonals, 21 semi-circles, 5 "Ts", 1 "Y", 27 tight boulder clusters, 27 loose boulder clusters, 5 rootwads, and 74 structures with a combination of boulders and logs. A total of 77 structures were cabled, 91 keyed in with boulders, and 50 entrenched into the banks.

After a 5-year event, 93 percent of the structures are still functional, providing sufficient amounts of intended habitat (Table 4). Of the functional structures, 44 were damaged from such problems as 20 logs scoured under, 17 partially broken out, one cutting around and 6 cable hole fractures.

Habitat—After treatment, surface area and water volume increased 14 percent and 65 percent, respectively (Tables 5 and UN-1). While pool habitat increased 21,984 m^2, glide habitat and main channel riffle habitat decreased 10,258 m^2 and 3,529 m^2, respectively. The creation of nine off-channel areas increased secondary channel pools and riffles by 2,857 m^2. In terms of limiting factors, all phases of habitat increased an estimated 7,000 m^2 for spawning, 27,000 m^2 for spring and summer rearing, and 24,800 m^2 for overwintering habitats. Bottom substrate changed dramatically, with large gravel increasing thirtyfold and small gravel one hundred twenty-six fold.

Spawning—Salmon and steelhead spawning ground counts have been conducted annually since the 1984-85 season. Since the 1984-85 spawning season, 18 coho/mile (ranging from 12-27), 3 steelhead/mile (ranging from 1 to 7), and 4 chinook/mile (ranging from 2 to 7) have been observed in the upper Nestucca River. Fish produced by the project will not return until the 1989-90 season for coho salmon and the 1990-91 season for steelhead.

Juveniles—Preliminary analysis of pre-project conditions revealed high densities of coho juveniles in pools and low densities of trout, steelhead and cutthroat parr in all habitats (Table UN-2). Although coho juvenile densities were lower in 1987, ODFW surveys found higher use in treated pools compared to control pools (Table UN-2). Based on the substantial increases in favorable habitat created by treatment structures, numbers of summer rearing salmonids should increase over pre-project levels. Because pool habitat showed the greatest increase, coho salmon should benefit most. A total of 32,000 coho, 2,850 trout, 2,375 steelhead, and 475 cutthroat juveniles are estimated to be produced by the project (Table 6).

Production—Annual benefit/cost analysis for an average full-spanning structure installed in the upper Nestucca River revealed a very favorable result. The average potential increase of 463 coho juveniles, 26 steelhead and 5 cutthroat parr per structure (based on types and amounts of habitat created) translates into an annual value (based on estimated catch) of $281 per structure (Table 7). The average cost of installing a full-spanning structure was $500.

Table UN-1. Habitat changes after treating 5.3 miles of the Upper Nestucca River, 1984 and 1987

	Surface Area (m^2)		Water Volume (m^3)	
Habitat Types	1984	1987	1984	1987
Riffles				
Low gradient	20,169	17,880	2,823	3,934
High gradient	6,126	6,198	977	1,266
Rapids	1,931	1,120	311	230
Cascades/Falls	1,188	687	192	148
Secondary channel	563	2,175	51	261
Glides	21,208	10,950	4,242	3,504
Pools				
Dammed	131	24,744	76	11,877
Plunge	998	2,827	509	1,329
Lateral/Under scour	11,233	2,655	5,617	1,301
Trench	3,463	6,828	1,732	3,482
Backwater	1,352	862	297	155
Secondary channel	346	1,591	69	350
Total	68,718	78,517	16,896	27,837

Table UN-2. Abundances and densities of summer rearing salmonids before and after treating the upper Nestucca River, 1985 and 1987

Fish	Pre 1985 (BLM Data)		Post 1987 (ODFW Data)
Pools		Maintenance control pools	
Number	7	Number	2
Avg. size (m^2)	298	Avg. size (m^2)	299
Coho/pool	401	Coho/pool	113
Coho/m^2 of pool	1.35	Coho/m^2 of pool	0.38
Pools & riffles		Main channel treated pools	
Trout/m^2	0.04	Number	6
Steelhead (1+)/m^2	0.01	Avg. size (m^2)	668
Cutthroat (1+)/m^2	0.002	Coho/pool	531
		Coho/m^2 of pool	0.79
		Off-channel control pool	
		Number	1
		Avg. size (m^2)	93
		Coho/pool	23
		Coho/m^2 of pool	0.25
		Off-channel treated pools	
		Number	22
		Avg. size (m^2)	29
		Coho/pool	24
		Coho/m^2 of pool	0.83

Lower Elk Creek Project (1986)

Elk Creek, the largest tributary on the upper Nestucca River, drains approximately 6,573 acres. Lower Elk Creek was severely impacted by a closely aligned road (reducing the riparian zone and constricting the channel), the 1972 flood and subsequent stream cleaning. The LEC project, the first of three projects in this drainage, was completed in the summer of 1986 at a cost of $25,000 (Table 1).

Initiated to improve winter and summer habitat primarily for coho salmon, this project treated 853 meters of a 1,899-meter reach. Work (a track-mounted excavator and hand labor) included the installation of 92 main channel and off-channel structures, along with the creation of seven new off-channel areas. This project has been monitored for habitat, juvenile and adult salmonids, and structural changes for five years - three pre and two post (Table 2). A total of 39 dams (full-spanning), of which 7 were diversion structures, 7 deflectors, and 39 cover structures (consisting of boulders, logs, rootwads, and combinations of each) were installed in LEC (Table 3). Most material was from off-site sources; however, some boulder and log structures (16) were constructed from on-site material. Most full-spanning structures were installed in "V", diagonal, "Y", or semi-circle shapes. Cover structures included tight and loose boulder clusters, rootwads, and combinations of boulder/wood material.

Presently, after a 5-year flood, 83 of the structures are fully functional, 9 damaged functional, and 3 repairable nonfunctional (Table 4). Thirty structures were secured by cable, 29 by boulders, and 30 entrenched into the bank. Problems included five log structures partially scoured under, six boulder structures partially broken out, and one cable hole fracture.

Habitat—Pre and post habitat surveys were conducted to estimate changes in habitat types and amounts after treatment (Tables 5 and LEC-1). A 64 percent increase in water surface area (11,471 to 18,038 m^2) and a 130 percent gain in water volume (2,640 to 6,077 m^3) occurred after treatment. Total pool habitat increased fivefold in surface area. All pools except plunge pools (the decrease in these pools was caused by including smaller pools in the post survey with high gradient riffles) increased in both size and number. Spawning gravels increased from an estimated 130 m^2 prior to treatment to 1,600 m^2 after treatment. Overall, gravels increased thirty-sevenfold and sand sevenfold, with larger substrates essentially remaining the same. Structures increased the amount of large woody debris in the channel, with the number of pieces increasing from 76 to 181, and total length increasing from 869 feet to 2,287 feet.

Spawning—Spawning ground counts were conducted for three seasons prior to treatment. Approximately 1.2 miles of lower Elk Creek were surveyed for adult salmonid use. Because of limited gravel areas, few salmonids spawned in this reach. Redds per mile average two coho salmon, three steelhead, and less than one chinook salmon between 1983 and 1986 (Table LE-2). After treatment, available gravels increased and adult use increased to 10, 14, and 20 redds per mile for coho salmon, steelhead, and chinook salmon (Table LE-2). Increased spawning was not directly attributable to the project but was the result of increased spawning areas created by the project.

Juveniles—Pre-project summer juvenile sampling of coho, steelhead, and cutthroat in 1980, 1985, and 1986 revealed good to fair densities of coho in pools and varying densities of steelhead and cutthroat parr (Table LEC-3). Post-project sampling by BLM and ODFW revealed significant increases in numbers of coho per pool and average densities per pool (Table LEC-3). Overall densities of steelhead and cutthroat parr showed no changes after treatment. However, based on increases in preferred habitat types after treatment, potential gains of 14,500 coho, 1,860 steelhead, and 950 cutthroat juveniles would occur in lower Elk Creek (Table 6).

Production—Based on potential estimated increases of 332 coho, 40 steelhead, and 21 cutthroat summer juveniles, the annual benefit per full-spanning structure would amount to $249 (Table 7). This annual benefit is significant, since the average installation cost of a full-spanning structure was $450.

Table LEC-1. Habitat changes in lower Elk Creek between 1985 and 1987

Habitat Types	Surface Area (m^2) Pre (1985)	Surface Area (m^2) Post (1987)	Water Volume (m^3) Pre (1985)	Water Volume (m^3) Post (1987)
Riffles				
High gradient	2,754	3,154	578	883
Low gradient	4,207	4,183	841	962
Rapids/Cascades/Falls	841	227	168	69
Secondary channel	120	1,734	12	191
Total	7,922	9,298	1,599	2,105
Glides	1,942	323	544	149
Pools (Total number)	(31)		(60)	
Dammed	191	6,536	65	3,202
Plunge	871	282	272	133
Lateral/Under scour	154	221	46	106
Trench	85	144	65	71
Backwater	150	505	24	121
Secondary channel	156	729	25	190
Total	1,607	8,417	497	3,823
Grand total	**11,471**	**18,038**	**2,640**	**6,077**

Table LEC-2. Adult salmonid use of lower Elk Creek before and after treatment, 1983-88

Fish	Spawning ground counts Pre (1983–1986)	Spawning ground counts Post (1986–88)1/
Coho salmon		
Adults/mile	7	25
Redds/mile	2	10
Steelhead		
Adults/mile	>1	19
Redds/mile	3	14
Chinook		
Adults/mile	10	39
Redds/mile	>1	20

1/No chinook salmon used Elk creek the fall of 1987 due to low flows.

Table LEC-3. Differences in salmonid densities and abundances before and after treatment of lower Elk Creek, 1980, 1985-87

	Pre		Post		
	Summer		Summer		
Fish	1980	1985-86	1987 (BLM)	1987 (ODFW)	Winter 1987 (ODFW)
Coho (Pools)1/					
Number/pool	134 (4)	166 (4)	344 (5)	427 (8)	152 (5)
Number/m^2 of pool	1.18	0.75	2.53	1.80	0.47
Steelhead (1+)					
Number/m	1.1	0.4	0.3		
Number/m^2	0.20	0.05	0.03		
Cutthroat (1+)					
Number/m	0.1	#0.1	0.1		
Number/m^2	0.02	0.01	0.01		

1/Pools were around 50 m^2 or larger in size.

Middle Nestucca River Project (1987)

The Middle Nestucca River Project was the second in a series of three projects to rehabilitate the upper Nestucca River after the impacts from Meadow Lake Dam. Primarily to improve coho salmon summer and winter rearing habitat, improvement of the Nestucca River middle section was completed in the summer of 1987, with installation of 42 structures in 1,770 meters of stream (Table 1). Approximately 36 percent (0.4 mile) of this reach was treated at a cost of $22,000. In addition to the installation of main channel structures, work included the creation and/or reopening of two off-channel areas. Evaluation has included habitat, juvenile, adult, and structural surveys over a period of four years (Table 2). A total of 3,005 feet of large wood and 50 yd^3 of boulders were used to install 7 dam, 2 diversion, 23 deflector, 4 cover, and 6 scour structures (Table 3).

Structures were constructed of large wood (47) and boulders (15) from onsite sources in the riparian, upslope zones and/or channel and floodplain. Structure shapes included three "Vs", 17 diagonals, 15 loose boulder clusters, 27 combination logs, rootwads, and boulders.

Habitat—Following treatment, surface area almost doubled and water volume increased fourfold (Tables 5 and MN-1). Pool habitat increased almost fivefold while glide habitat decreased by more than two-thirds. The most significant change was in dam pools which increased from zero to 7,450 m^2. Secondary channel and plunge pool areas tripled and doubled, respectively, while lateral scour and trench pool areas slightly decreased. Large woody debris increased substantially after treatment, with the number of pieces doubling and total length increasing almost sixfold (Table MN-1).

Juveniles—Based on changes and increases in available habitat, salmonid juveniles would potentially increase by 8,645 coho salmon fry, 403 trout fry, and 421 steelhead and 70 cutthroat parr (Table 6).

Production—Based on potential increases of 1,235 coho, 60 steelhead, and 10 cutthroat summer juveniles (Table 7), the middle Nestucca project has the highest annual benefit per full-spanning structure ($510) of all projects.

Table MN-1 Habitat and large woody debris changes in 986 meters of the Middle Nestucca River, 1984 to 1988

Habitat Types (Numbers)	Surface area (m^2) Pre	Surface area (m^2) Post	Water volume (m^3) Pre	Water volume (m^3) Post
Pools				
Lateral scour	1,158 (6)	1,113 (4)	519	758
Trench	153 (1)	0	84	0
Backwater	19 (1)	21 (1)	4	6
Plunge	293 (1)	824 (9)	178	538
Secondary channel	390 (6)	1,276 (8)	76	460
Dammed	0	7,450 (8)	0	4,775
Total	2,013 (15)	10,684 (30)	861	6,537
Gildes	2,285 (8)	788 (3)	385	435
Riffles				
Low gradient	4,349 (15)	2,650 (10)	620	787
High gradient	616 (4)	684 (3)	150	234
Secondary channel	451 (5)	620 (7)	34	115
Grand Total	**9,714 (47)**	**15,426 (53)**	**2,050**	**8,108**
Large woody debris				
Number of pieces	43		91	
Total length (ft)	618		3,338	
Average diameter (ft)	1.4	1.8		
Average length (ft)	14		37	

Upper Elk Creek Project (1987)

Upper Elk Creek Project is the second phase of rehabilitating the Elk Creek drainage. This project, which was not fully completed in the summer of 1987, treated a 2,150-foot (67 percent) section of a 3,200-foot reach of stream at a cost of $23,000 (Table 1). Similar to the lower Elk Creek, this project was initiated to improve winter and summer rearing for coho salmon. Monitoring has included one year of pre and post surveys for habitat and juvenile salmonid changes, five years of pre and one year post surveys for adult spawners, and a structural survey. Upper Elk Creek is a relatively remote reach of stream running through a mature Douglas-fir and western red cedar riparian zone. This reach was cleaned after the 1972 storm, and consequently, little instream woody structure was present. A total of 40 conifers were felled from the riparian zone and upslope areas to provide structural material for rehabilitation. Logs were secured mostly by pinning with rebar and some cabling where appropriate anchoring material was available. Using a track-mounted hydraulic excavator and hand labor, 77 structures and 2 off-channel areas were constructed.

A total of 18 dam (full-spanning), seven deflectors, and 52 cover/scour structures (log jams, rootwads, boulder groupings, and logs) were installed in UEC (Table 3). Most structures, consisting of on-site felled large conifers, were installed in diagonal (31), "V" (8), semi-circle (8), and loose boulder (21) shapes. Presently, after a 5-year flood, 74 of the structures are fully functional and 3 are damaged functional (Table 4). Twelve structures were secured by cable, 46 by rebar, 22 by boulders, and 18 entrenched into the bank. Problems include three large pinned deflector logs that have dislodged and shifted position but still remain in the low flow channel.

Habitat—Pre and post habitat surveys were conducted to estimate changes in habitat types and amounts after treatment. A 32 percent and 70 percent increase occurred in surface area and water volume, respectively, with the greatest increases in dam, backwater, and plunge pools (Table 5 and UEC-1). Total pool habitat increased over fivefold, from 23 percent prior to treatment to 77 percent after. Large woody debris increased substantially after treatment. Total water volume increased threefold from pre project levels. During reconstruction work, a total of 104 pieces of wood, totalling 3,170 feet, were placed in the channel (Table UEC-2). These woody structures trapped/recruited an additional nine pieces, totaling 370 feet of large woody debris.

Juveniles—After treatment, changes in types and amounts of habitats created a potential increase in juvenile salmonids. The estimated potential increases in summer populations of juvenile salmonids after treatment were 6,487 coho salmon, 2,794 trout, and 582 steelhead, and 323 cutthroat parr (Table 6).

Spawning—Prior to treatment, adult use of upper Elk Creek between 1982 and 1987 averaged 8 coho salmon redds per mile, 17 steelhead redds, and 2 chinook redds (Table UEC-3). After treatment in 1987-89 spawning activity increased to an average of 34 for coho redds and averaged 15 for steelhead redds per mile. Because of low fall flows in 1987, no chinook salmon spawned in this reach.

Table UEC-1. Habitat changes in Upper Elk Creek between 1985 and 1988

Habitat Types (Numbers)	Surface area (m^2)		Water volume (m^3)	
	Pre (1985)	Post (1988)	Pre (1985)	Post (1988)
Pools				
Dammed	364 (4)	4,666 (19)	279	2,333
Lateral scour	447 (9)	269 (7)	139	189
Plunge	82 (12)	392 (18)	23	176
Backwater	8 (8)	295 (16)	4	102
Secondary channel	142 (10)	60 (3)	36	7
Total	1,043 (43)	5,682 (63)	481	2,807
Glides	651 (15)	105 (3)	146	26
Riffles				
Low gradient	2,098 (14)	1,118 (12)	394	110
High gradient	673 (4)	270 (6)	137	51
Secondary channel	77 (6)	161 (5)	6	12
Total	2,848 (24)	1,549 (23)	537	173
Grand Total	**4,542 (82)**	**7,336 (89)**	**1,164**	**3,006**

Table UEC-2. Changes in large woody debris (greater than 1' by 10') after treatment in upper Elk, 1985 and 1988

Woody Debris	Pre	Post
Number of pieces	12	125
Average diameter (ft)	2.1	2.1
Total length (ft)	180	3,540
Average length (ft)	15	30
Log structures		
Full-spanning		
Number		12
Pieces		27
Total length (ft)		1,580
Partial spanning		
Number		38
Pieces		77
Total length (ft)		1,590
Recruited large wood		
Pieces		9
Total length (ft)		370

Table UEC-3. **Adult salmonid use of upper Elk Creek before and after treatment, 1982-1988**

Fish	Pre (1982-1987)	Post (1987-88)
Coho salmon		
Adults/mile	52	102
Redds/mile	8	34
Steelhead		
Adults/mile	37	35
Redds/mile	17	15
Chinook		
Adults/mile	6	1*
Redds/mile	2	0*

*Low flow conditions in the fall prevented

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